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ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV No. 3. MARCH, 1953

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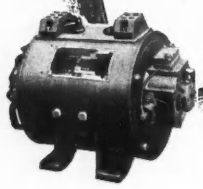

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CONTENTS

	Page
The Blue Pages	73
Editorial — Wind Power — Plant Stockpiling — Cast-Iron Crankshafts, Present and Future	77
Semi-Graphical Method for the Study of Vibrating Systems with Vibration Dampers	78
Workpiece and Surface Temperatures in Milling	81
Recent Developments in the Soviet Machine Tool Industry	83
The Casting of Milling Cutters of Grey Cast Iron with Carbide Inserts	86
Effect of Low and High Temperature on Physical Properties and Machinability of Carbon Steels	87
The "Transferometer"—An Apparatus measuring the Performance of Servomechanism Elements	91
Rubber and Leather bonded to Die Castings for Oil Seals	94
The Correct Dimensioning of 3-Phase Motors	95
An Objective Photometer for the Measurement of Low Intensities of Illumination	97
New Materials, Processes and Equipment	99
Classified Abstracts	103
News of the Month	105

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *SPECIAL THERMOCOUPLE*

The need for an instrument to measure transient temperatures arises in numerous heat transfer investigations. Because of their simplicity and comparatively rapid response, fine-wire thermocouples are usually employed. However, in certain applications, fine-wire thermocouples are unsatisfactory because of their lack of strength and difficulties in positioning the junction at the point to be investigated. Furthermore, the minimum size of the junction, which affects the rate of response, usually is limited to the wire diameter. According to a recent announcement, a special thermocouple has now been developed which has a junction thickness of only one micron, that is, one thousandth of a millimetre or 0·000039 in. Yet the instrument is said to be of such rugged construction that it may be employed for measuring extremely rapid temperature changes in regions of high stress. The major parts of the instrument are the probe, the body, the terminal posts and an insulator. The most important part is, of course, the probe which contains the junction. The probe consists of a thick-walled steel tube which at one end is plated with a layer of nickel having a thickness of one micron. The interface between the nickel plating and the underlying end of the steel tubing is the plane at which the thermal electromotive force is generated. The lead wire to the plating is mounted in the centre of the tubing. This wire is also made of nickel and is coated with an oxide of nickel which serves as electrical insulation beneath the nickel wire and the steel tubing. The probe of 0·09 in. diameter is held in a steel body equipped with external threads which are used to mount the unit, and also contains the binding post. The overall length of the couple is approximately 3 in. In the latest design, the probe itself is threaded so that no separate body is required, and the nickel wire is connected directly to the external lead so that no insulator is required.

● *WELDING CARBON TO MOLYBDENUM*

The development of nuclear techniques has raised a host of unusual engineering problems, especially in the metallurgical field. An interesting example is the joining of carbon to molybdenum by welding, which at first sight would appear to be an impossible task. In fact, the process as such is quite simple, the only equipment required being an atomic hydrogen torch. It appears that the presence of carbon close to the metal serves to lower the melting point of the metal, so that at an appropriate temperature the metal flows and wets the heated carbon. It is believed that there is a formation of a carbide and this carbide not only dissolves in the heated metal so as to bond with it, but also flows into the molecular interstices of carbon and bonds or interlocks therewith. The precise mechanism of the junction or union between the metal and the carbon is not at present known, but there is evidence of intermolecular engagement, the weld being very hard and strong. It has been found that some metals which do not produce carbides at the temperature involved, for example copper, apparently cannot be welded in this way. Although tungsten does not form a carbide under the prevailing conditions, it appears to wet well when a molybdenum welding rod is used. If it is desired to join carbon to copper, it can be accomplished by first welding together carbon and molybdenum and then joining the molybdenum and the copper, for example by hard solder. When welding carbon to molybdenum and then welding the molybdenum to carbon, the intermediate molybdenum can be very minor in amount, so that to all practical purposes carbon is welded to carbon.

● *DRILLING BY ELECTRONS*

To the steadily growing list of new machining techniques the drilling of holes by direct electron bombardment can now be added. According to the nature of the process, the production of the electron beam must be carried out under a high vacuum, and the apparatus to be employed for drilling operations incorporates features for directing and concentrating the electron beam which resemble those employed in electron microscopes. The operating voltage to be maintained between the cathode and the workpiece forming the anode is given by the inventor as 50,000 volts in the case of a typical instrument. By evaporating the material bombarded by the electron stream, holes of varying diameters can be drilled. The process is limited to the drilling of extremely small holes, but by employing an electron beam of relatively high current density, holes several millimeters in depth can be drilled. It is stated that holes may be drilled in such diverse materials as tungsten, glass, porcelain, palladium silver alloys, steel, aluminium oxide, and indeed almost any material of

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any hardness. These holes may be of a diameter between 0·1 and 0·01 mm and may have a length between 3 mm and 0·1 mm, drilling times ranging from one second to 20 seconds. Small slots and cuts of any desirable form may also be produced. As drilling must be carried out under a high vacuum, the requisite vacuum pumps, etc., must be provided. Provision for the removal of the metal or other vapour produced by the drilling operation must be made. Location of the hole is carried out by means of a microscope and a set of reflecting mirrors. The drilling of diamonds is carried out by a special technique including the admission of oxygen to the point of electron impingement, the electron beam being adjusted to raise the temperature of the diamond to no more than some 300° C.

● *REFRIGERATION SYSTEM WITHOUT ROTATING SEAL*

In the design of refrigeration equipment, much ingenuity has been applied to the development of the rotating seals usually found indispensable. The most successful solution of all must, of course, be a design in which rotating seals are dispensed with altogether, and this radical step is followed in the construction of a small automatic, completely self-contained, ice flake making machine. In this unit, a hermetically sealed refrigerating system rotates on a vertical hollow shaft. By uniting compressor, condenser, condenser fan, accumulator, relay and evaporator in a rotating assembly, it has been found possible to seal the refrigerant without the use of flared joints or rotating seals. Furthermore, should serious trouble arise in the system, it can be removed as a unit from the ice-maker and sent back to the factory for repair. Only the water sprays, ice cutter, water trough piping and ice chute are stationary. A circular coil condenser is provided which employs air instead of water as the cooling medium. The cylindrical evaporator drum has two shells, the inner one of stainless steel. The refrigerant, consisting of Freon 22, is admitted in liquid state to the annular space between the two shells, where it boils to a gas and whence it is returned to the compressor. The ice formed on the outside of the drum is removed and passed in the shape of flakes into an ice chute by means of a stainless steel scraper blade, the action of which is assisted by a six-bladed ice-cutter. In order to prevent the accumulation of minerals and solids in the water recirculating system, an automatic blow-down unit is incorporated.

● *THREE DIMENSIONAL FLOW MEASURING PROBE*

A recent report describes the design, development, and operation of a three-dimentional flow measuring probe. This instrument was designed to satisfy the need for a versatile device which could be used for fluid flow studies, especially studies in combustion chambers, compressors and diffuser sections. The sensing element of the probe is a sphere attached to a support tube in such a way that the sphere has two degrees of freedom, one of translation along the axis of the support tube and the other of rotation about this same axis. In this respect it shows a similarity to the two-dimensional Pitot static tube. But the latter has but two degrees of freedom, one of translation along the axis of the support tube and one of rotation about the support tube axis. Therefore, it is impossible to measure flow which does not lie in a plane at right angles to the support tube axis. The probe, however, is a three-dimensional type instrument in that the pitch and yaw angles of the velocity vector at a point in a fluid stream as well as the static and dynamic pressures at this point may be determined by its use. Pitch angles of the velocity vector are measured by a particular arrangement of openings on the surface of a sphere. The yaw angle can be determined through the full range of ± 180 degrees and the pitch angle through a limited angle of ± 45 degrees. The instrument could be modified to give readings for greater pitch angles. Static pressure is observed directly from readings of manometers or other pressure measuring devices connected to the instrument, and dynamic pressure is determined from the observed pressures at the several openings on the surface of the sphere.

● *MAGNETIC FORCE WELDING*

In the spot welding process, quality of the weld can be greatly improved by a synchronised application of electrode force, thus making it practicable to weld on a rising electrode force wave. The importance of this feature has been increasingly recognised in recent years, and it is now an accepted fact that fast follow-up improves weld quality, decreases expulsion, arcing and tip pick-up. Moreover, application of a rapidly rising electrode force makes it possible to use a lower initial electrode force which has two advantages. Firstly, it increases the heat from a given current because of higher contact resistance, and, secondly, it provides concentrated heat from projections on materials such as soft aluminium or magnesium, which would collapse under the electrode force of conventional welders. The ideal source of synchronised force must obviously be the welding current itself, and in principle it is easy enough to visualise an electro-magnetic device passed by the welding current and exerting the required variable electrode pressure. Considerable difficulties were, however, encountered in the practical execution of such a scheme and much patient study and development work were required to develop a device having the operating characteristics and flexibility required in practice. In its present form the device incorporates seven possible adjustments, two of them mechanical,

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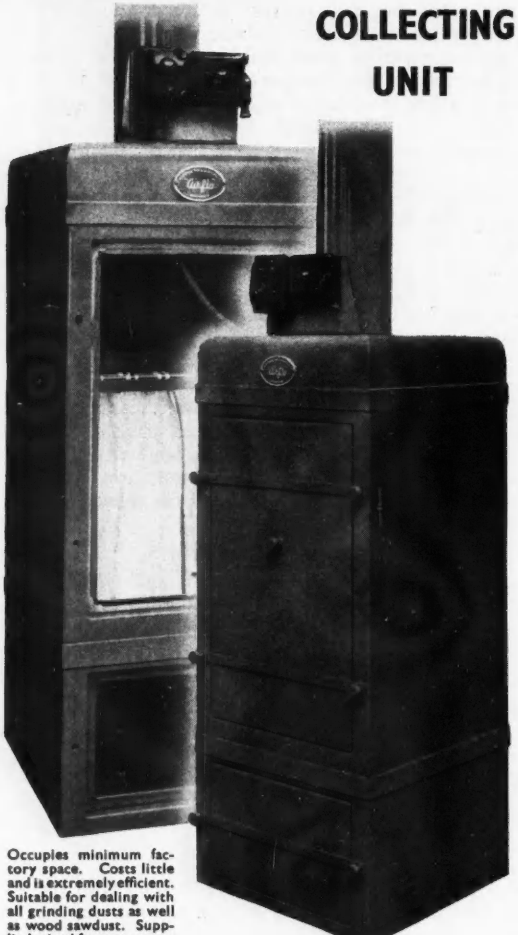

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● *SULPHUR IMPREGNATED SINTERED BEARINGS*

The employment of oil impregnated sintered iron compacts as bearing material is subject to a number of limitations of which the low specific pressure permissible is perhaps the most important. Any overloading in this respect leads to excessive heating of the bearing with consequent loss of oil from the pores of the material. A number of attempts has been made in the past to improve the bearing qualities of sintered iron compacts, and thorough investigations of the influence of the size of powder, the compacting pressure, the sintering process and other manufacturing variables have been carried out. Experiments were also made with a view to improving the bearing characteristics by adding other metallic or non-metallic powders to the iron powder, or by impregnating the porous sintered product with special materials. A most successful treatment was found to be the impregnation of the sintered iron with molten sulphur forced under pressure into the pores of the piece. The friction-reducing action of the sulphur is explained by the formation of thin sulphide layers on the bearing surface. These sulphide layers are continually renewed in operation as long as sulphur is left available in the pores. Sulphur can be introduced at either 120° C or 400° C at which the molten sulphur has its optimum fluidity. The amount absorbed must of course depend upon the porosity of the sintered part. A recent paper containing hitherto unpublished data on the frictional properties of such bearings, provides interesting information over a wide range of specific pressures up to 700-750 kg/cm.^{2} Experimental bearings made with Cr-Ni-Mo steel powder, also impregnated with sulphur, were found to support specific surface pressures as high as 900 kg/cm.^{2}

● *ALUMINIUM HONEYCOMB SANDWICH STRUCTURES*

Aluminium foil honeycomb sandwich structures are now in quantity production for such parts as aircraft flooring, bulkheads, partitions, ducts, doors, ailerons, trim tabs, and leading edge slats, and for guided missile wings and radar reflectors. Compared with fabric core honeycomb structures, aluminium foil has several advantages. Its high specific strength values in shear and compression and its extremely high shearing modulus make it a highly desirable material from the structural point of view; while its resistance to corrosion and fungus growth and its high strength under various environmental conditions such as extremes in temperature and humidity are pre-eminently important for a material to be used in aircraft construction. Except in some constructions such as specialised low density cores, the compressive strength of this material is higher than either that of foamed plastic structures or of fabric core honeycomb. Moreover, its production can be more rigidly controlled than that of most foams. In addition, reinforcements can be added in the form of reinforcing strips through the centre of the core to improve strength in localised sections. Briefly, a structural aluminium sandwich consists of two high-strength thin facings separated by a low density aluminium foil core. The core and the facing are bonded with heat and pressure into an integral panel, using a thermosetting synthetic resin adhesive. The core can be obtained in $\frac{1}{4}$ and $\frac{3}{8}$ in. hexagon cells, and experimentally in $\frac{1}{2}$, $\frac{5}{8}$ and $\frac{3}{4}$ in. cells. The greater the cell density, of course, the higher the strength. The facing material, also bonded by a phenolic adhesive, is also aluminium and may be used in varying thicknesses. A heavier gauge facing is frequently used on the compression side of panels subject to high bending moments. Magnesium facing, which is less durable than aluminium facing, may be used for partitions and panels which are lightly loaded.

● *QUICK-ACTING GAS SAMPLER*

A quick-acting gas sampler has been evolved which makes it possible to sample the gas mixture in the cylinder cavity of internal combustion engines existing at a given instant. This sampler was designed for use in research into the mechanism of engine knock with a view to obtaining information that will make it possible to use automotive fuels in a more efficient manner. In order to obtain significant data on the chemical processes taking place in the cylinder of the engine, some knowledge is required of the proportion of reactants and products present at various times during the combustion cycle. It is obvious that multi-stage combustion reactions of this type are especially difficult to study because of the very short duration of each stage—varying as it does between 0·1 and 1 millisecond—the extreme complexity of the reaction mechanism, and the fact that many of the important particles are free radicals with half-lives of one millisecond or less. Thus, if the combustion gases are to be sampled, the samples must be taken over extremely short intervals during a single cycle of operation, and the reaction must be frozen almost completely upon removal of the sample from the combustion chamber. The sampling device developed essentially consists of a flanged piston valve moving in an evacuated

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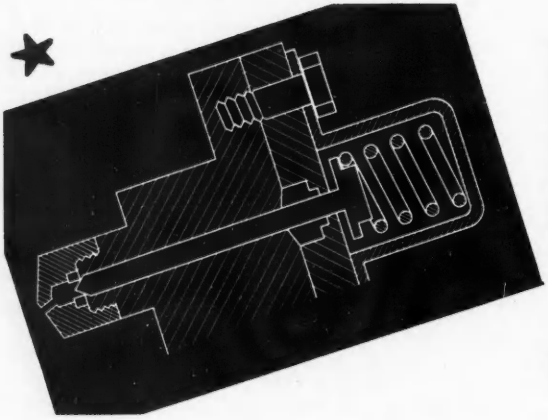

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chamber. The valve chamber is connected at its upper end to a vacuum pump and an evacuated sample container. At its lower end the sampler is designed to fit a sparking plug hole. The valve is electrically triggered at the desired instant and gases are passed through the valve into the container until the valve has reached its extreme position, when the container is automatically sealed by the valve.

● *MERCURY JET SWITCH*

The latest type of mercury jet switch is a high-speed electrical, multiple selector switch which has very low switching transients. It was developed to provide rapid scanning, monitoring, and displaying of a large number of electrical signals. A jet switch, for example, has been operated at rates up to 1,800 interruptions per second, with a noise level of 20 microvolts across 200 ohms. This type of switch consists of a bakelite commutator having a circular arrangement of contact pins about a rotor. A fine jet of mercury is emitted from this rotor to scan each contact in sequence as the rotor revolves. For this purpose, the jet is mounted on the upper edge of an inverted cone, the apex of which is submerged in a pool of mercury. Inside this cone is an enclosed passage way, through which mercury rises by centrifugal force to the jet when the cone is revolved. This pumping is self-priming if the level of mercury is sufficiently high. Mercury-wetted contacts are used so that switching takes place between liquid mercury surfaces. This identity of contact surface material and the absence of friction virtually eliminate switching transients. Switches of this type built to date have 60 contacts arranged in a $2\frac{3}{4}$ in. diameter circle. Contacts for low-voltage switching are made of 30-mil platinum wire. A 10-mil diameter jet is used because it provides a continuous stream of droplets upon hitting a contact. In this way, only the contact being hit is electrically connected to the pool. During the open-circuit interval, the jet strikes a metal backplate extending into the mercury pool. These switches are operated in air, but are hermetically sealed to prevent continued oxidation of the mercury. Besides thermocouple switching, this switch should be useful for scanning signals from strain gauges, transducers, and temperature resistance elements.

● *MANUFACTURE OF MICROSTRIP*

Microstrip is a new system of microwave circuitry, the main features of which are very light weight, compactness and very low cost. It promises to replace coaxial cables and waveguides in many present microwave transmitters and receivers. The new system must not be confused with ordinary printed circuits. The design of a hybrid circuit is drawn in ink on tracing cloth to produce a master. In designing the master drawing, the dielectric constant of the plastic sheet, its thickness and its outline must be carefully considered for optimum electric characteristics. The master drawing is then reproduced as a photographic negative. The plastic sheet used is covered on each side with a continuous film of copper. The next step is to flow photosensitive compound over one side of the copper. The photographic emulsion used is insensitive to ordinary room illumination. The sensitised sheet is then dried and the negative is placed over the sensitised copper, and both are placed in a vacuum frame to provide positive contact. The frame is then exposed to an arc light and subsequently developed. The developer washes away the sensitised coating where the light could not reach it through the negative. The desired design is left covered with the coating that will protect it against the etching bath. The copper film on the back is then entirely covered with a permanent acid-resisting plastic. The sheet is then placed in the etching bath, which etches away all unprotected copper, thus leaving only the design on one side of the sheet. The shape and the dimensions of the conducting areas then determine the electrical characteristics of the finished microstrip, which is now ready for assembly with the component parts concerned.

● *MAGNETIC BALL RELAY*

A shockproof, hermetically sealed relay, capable of operating at high speeds of over 100 cycles per second, has been developed for use on direct current circuits. The outstanding feature of this relay is the use of magnetic balls as the contact means, providing new contact surfaces at each operation and preventing mis-operation under vibration in locations such as aircraft and automobiles. A special non-magnetic plating applied to the surface of the balls and of the pole pieces is said to safeguard a long service life of the contacts, and to avoid sticking such as is liable to be caused by current interruption. The material used in the manufacture of these balls is also claimed to prevent contact holding due to residual magnetism. The pole pieces are insulated from each other and constitute the terminals of the circuit to be closed. Upon de-energising, the balls release and fall to one side of the chamber and interrupt the circuit. The manufacturers of this relay claim that the proportions of pole pieces, chamber and number of balls are so chosen that accidental bridging between the terminals cannot occur even with shaking of the relay, nor is its functioning influenced by altitude.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV. No. 3. MARCH, 1953

Wind Power

ENGINEERS and planners interested in the utilisation of our energy resources must have noted with satisfaction the news about the wind-driven generator now nearing completion in Britain. As reported in our last issue, this generator, which has a capacity of 100 kW, is being built for the British Electricity Authority and is based on a new system attributed to M. J. Andreau, of France.

Plant of such small capacity is, of course, only of interest at isolated locations for pumping water or generating d.c. power to charge storage batteries, a field well catered for by conventional units now on the market. The significance attached to the British experiment is that it relates to a pilot plant which, it is hoped, will eventually enable the design of plants up to 1000 kW. Existing plants of this output have severe limitations, which do not beset the new system.

The drawbacks of earlier systems were attributable either to the generator being mounted on top of the tower, which requires heavy and costly equipment and maintenance, or, in case of a ground-installed generator which necessitates gearing and shaft between propeller and generator, to " yaw instability," i.e., a tendency of the propeller to turn itself out of the direction of the wind. In the Andreau system, these disadvantages are eliminated as there is no mechanical connection between propeller and turbine.

It is interesting to speculate that in spite of the advances made in aerodynamics, the harnessing of wind power largely remained an elusive problem, and that a solution seems to be possible only now, when atomic power is nearing realisation.

Plant Stockpiling

Early in January, before the change in political administration, the Truman budget contained a request for $500 million for the procurement of machine tools, metal-working and capital equipment. This is part of an expenditure of $2000 million proposed by the advisory committee on production equipment, known as the Vance Committee. The U.S. Government already owns or controls an inventory worth $6,000 million. Another $2,000 million would increase governmental ownership of tools and equipment by about 5 per cent to a total of about 25 per cent.

All this does not mean that the U.S. Government intends to go into business on its own, as this production capacity is destined for strictly military purposes. It simply means that the Government adopts the recommendation of the Vance Committee to " stockpile " plants instead of arms.

The report of the Vance Committee, submitted to the " Office of Defense Mobilization," comes to the conclusion that it is both safer and cheaper to stockpile productive capacity than to try to produce, store and maintain military equipment.

It is pointed out that if a stock of, e.g., 5,000 tanks became obsolete, it would involve a loss of at least $1,000 million. On the other hand, the cost of upkeep and modernisation of existing production facilities would require only a fraction of that cost.

In the opinion of the Committee, wrong practices after the first and second World Wars are to be blamed for the fact that " outmoded production equipment and processes are still being used for important military items, such as rifles." Obviously, after the two wars, production plant and equipment were allowed to deteriorate as there were no appropriate funds available for their modernisation.

For us in Great Britain, within our much more limited means, there should be much food for thought in the conclusions of the Vance Committee.

Cast-Iron Crankshafts—Present and Future

Many efforts have been made to produce cast-iron crankshafts, and results have in some cases been encouraging, particularly for small engine sizes. Cast-irons considered from the point of view of the engine maker, and not from that of the metallurgist, have a number of interesting features. They enable a saving in machining time and cost, and thus allow the lathes, etc., to be used with a better turnover on a larger number of jobs. Cast-irons have higher damping properties and generally a lower notch sensitivity than steels.

However, in the range of crankshafts for medium and large-size engines, the use of cast-irons has not been as extensive as might have been expected. A large variety of irons has been tried, from grey flake cast-irons, acicular irons, nodular irons, and high-test irons, to the special irons such as Meehanite and semi-steels. Recently, spheroidal irons have been extensively considered. The fact remains, that although there is so much in favour of cast-irons, their use for production purposes has, generally speaking, been

(*Concluded on page* 104)

AUSTRIA

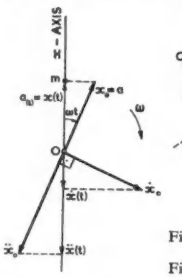
Semi-Graphical Method for the Study of Vibrating Systems with Vibration Dampers

By W. KURZEMANN. (From *Maschinenbau und Wärmewirtschaft*, Vol. 7, No. 12, December, 1952, pp. 197-201, 7 illustrations.)

Graphical methods have the advantage of giving a simple, clear and visual representation of the vibration conditions of a system. Each force and amplitude of displacement is indicated by a vector with a corresponding phase-angle. This article describes a graphical procedure suitable for practical applications on the basis of a two-mass system, one mass of which is a vibration damper.

REPRESENTATION OF HARMONIC MOTION

When a concentrated mass m vibrates with a " simple harmonic " (i.e., sinusoidal) motion along an axis about a zero-position, the motion can be determined graphically by means of rotating vectors, as shown in Fig. 1.



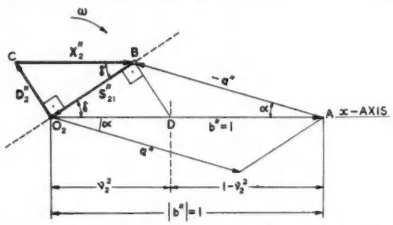


Fig. 1 (left). **Instantaneous values of vibration amplitude, velocity and acceleration.**
Fig. 2 (above). **Vibration diagram for the auxiliary system.**

The vibration amplitude is given by the vector **a**, which rotates about O with a phase velocity ω. At any instant t, the phase-angle of **a** with the reference axis is ωt and the instantaneous amplitude $x = a \cos \omega t$ is obtained as the projection of the vector **a** on the x-axis. In the same way, the velocity and acceleration of the mass m, that is,

$$\dot{x}(t) = -a\omega \sin \omega t = a\omega \cos [\omega t + (\pi/2)]$$

and $$\ddot{x}(t) = -a\omega^2 \cos \omega t = a\omega^2 \cos [\omega t + \pi]$$

can be represented as the projections of rotating vectors with the lengths $a\omega$ and $a\omega^2$, respectively.

Generally, therefore, any variable which is a simple-harmonic function of time can be represented by a rotating vector.

BASIC FACTORS FOR DAMPING

In every real system there are energy losses due to damping influences. In a system with linear damping, i.e., with damping proportional to velocity, the damping force is

$$\mathbf{D} = -c\,\dot{\mathbf{x}}\ [\text{kg}]$$

where c = damping coefficient [kg sec/cm]. Introducing the spring stiffness k [kg/cm] and ω_n = phase velocity of the natural vibration of the system [rad/sec], so that $\omega^2 = k/m$, we can define the " relative damping coefficient " γ by the relations

$$\gamma = c/(2\,m\,\omega_n) = c\,\omega_n/(2\,k).$$

If an external force **P** were applied statically, the system would have a static deflection $\mathbf{a}_s = \mathbf{P}/k$. This deflection is magnified by resonance if **P** is a sinusoidal force with a phase velocity ω. The vibration amplitude a obtained under dynamic conditions is related to the static value a_s by means of the " resonance function "

$$M = a/a_s = 1\Big/\sqrt{[1-(\omega/\omega_n)^2]^2 + (2\,\gamma\,\omega/\omega_n)^2}$$

At resonance, $\omega/\omega_n = 1$, and the resonance function has the value

$$M^* = 1/(2\,\gamma) = k/(c\,\omega_n)$$

which is known as the " dynamic magnifier " of the system.

Furthermore, it is convenient to introduce the " damping ratio " ψ defined as the ratio of the energy dissipated per cycle and the strain energy of the system, i.e.,

$$\psi = (\pi\,c\,\omega_n\,a^2)/(\tfrac{1}{2}\,k\,a^2) = 2\,\pi\,c\,\omega_n/k$$
$$= 4\,\pi\,\gamma = 2\,\pi/M^*.$$

The damping force can therefore be written as

$$\mathbf{D} = -k\,\dot{\mathbf{x}}/(\omega_n\,M^*)$$

The dynamic magnifier gives a visual representation of damping and will be used for further relations.

The value of the damping ratio ψ for soft rubber of the types used in engineering applications shows slight variations with different frequencies and amplitudes. Oscillograph recordings of hysteresis loops of rubber (loops of displacement plotted against force) are used to determine ψ from the ratio of the loop area to the area $k\,a^2/2$ of the strain-energy triangle. For rubber we may therefore write the approximate relation

$$k\,a^2/2 = \pi\,c_m\,\omega\,a^2$$

where c_m = mean value of the damping coefficient. Thus c_m is determined as

$$c_m = (\psi\,k/2)/(\pi\,\omega) = \text{const} \times \frac{1}{\omega}\ [\text{kg sec/cm}]$$

and the damping force is

$$\mathbf{D} = c_m\,\omega\,\mathbf{a} = (\psi/2\,\pi)\,k\,\mathbf{a} = \mathbf{S}/M^*\ \ [\text{kg}]$$

where $\mathbf{S} = k\,\mathbf{a}$ = spring force [kg] and $M^* = (\psi/2\,\pi)$ = dynamic magnifier. Thus, with rubber, the damping coefficient c_m is inversely proportional to ω and directly proportional to the spring force S.

VECTOR DIAGRAM FOR THE AUXILIARY SYSTEM

The main system can be represented by a mass m_1 connected by means of a spring of stiffness k_1 to an infinitely rigid support situated overhead. The mass m_2 of the auxiliary system is elastically connected to m_1 by means of a spring k_2. The system is vibrated by an external force **P** acting on m_1.

The damping provided by the auxiliary system can be obtained in various ways. If a stationary dashpot is connected to m_2 we have " absolute damping." If the dashpot casing is also allowed to vibrate freely, we have " relative damping." Finally, if the spring element k_2 is made of rubber, we have " rubber damping " between the masses m_1 and m_2. Our two-mass system will be assumed to incorporate rubber damping.

The diagram of the auxiliary system will now be considered separately (see Fig. 2). Let **a** = vibration amplitude of m_1 about O_1, and **b** = amplitude of m_2 about O_2, with a phase lead α relative to **a**. The relative-amplitude vector is $\mathbf{s}_{21} = \mathbf{b} - \mathbf{a}$.

The forces at mass m_2 are as follows :—

inertia force : $\mathbf{X}_2 = m_2 \omega^2 \mathbf{b}$,
damping force : $\mathbf{D}_2 = c_2 \omega \mathbf{s}_{21}$,
spring force : $\mathbf{S}_{21} = k_2 \mathbf{s}_{21}$.

These forces are in equilibrium and form, therefore, a closed triangle. We introduce for the auxiliary system the " frequency ratio "

$$\nu_2 = \omega/\omega_{n2} \quad \text{where} \quad \omega_{n2}^2 = k_2/m_2$$

and the " auxiliary system dynamic magnifier ":

$$M_2^\star = k_2/(c_2\,\omega_{n2})$$

We can therefore write : $\mathbf{D}_2 = k_2\,\mathbf{s}_{21}\,\nu_2/M_2^\star$ and $\mathbf{X}_2 = k_2\,\nu_2^2\,\mathbf{b}$.

It is useful to reduce these vectors to non-dimensional quantities by dividing the forces by $|\,k_2\mathbf{b}\,|$ and the amplitudes by $|\,\mathbf{b}\,|$. We thus obtain :

$\mathbf{b}/b = \mathbf{1}$, a vector along the x-axis,
$\mathbf{a}'' = \mathbf{a}/b$
$\mathbf{X}_2'' = \mathbf{X}_2/(k_2\,b) = \nu_2^2$
$\mathbf{D}_2'' = \mathbf{D}_2/(k_2\,b) = \mathbf{s}_{21}\,\nu_2/(b\,M_2^\star)$
$\mathbf{S}_{21}'' = \mathbf{S}_2/(k_2\,b) = \mathbf{s}_{21}/b$

Fig. 2 is then constructed as follows :—(1) Draw a vector $\mathbf{a}'' = \overrightarrow{\mathbf{O_2A}}$ of unit length along the x-axis. (2) Determine the angle δ between the x-axis and the line of action of $\mathbf{S}_{21}''$ by means of the relation

$$\tan\delta = |\,\mathbf{D}_2/\mathbf{S}_{21}\,| = \nu_2/M_2^\star$$

(3) From the point D (corresponding to the value of ν_2^2) on the x-axis, erect a perpendicular to the line of action of $\mathbf{S}_{12}''$, intersecting this line at point B. Then $\overrightarrow{\mathbf{BO}_2} = \mathbf{S}_{21}''$. (4) From B, draw a parallel vector to the x-axis, of length ν_2^2. This is the spring force vector $\mathbf{X}_2'' = \overrightarrow{\mathbf{CB}}$. (5) From C, drop a perpendicular on to $\mathbf{S}_{21}''$. This gives the damping force $\mathbf{D}_2'' = \overrightarrow{\mathbf{O_2C}}$.

Thus, for each value of the frequency ratio ν_2, it is possible to construct the non-dimensional diagram of Fig. 2, when $M_2^\star$ (in other words c_2) is given.

VECTOR DIAGRAM FOR THE MAIN SYSTEM

The vector diagram of the main system is shown in Fig. 3. The mass m_1 vibrates with an amplitude $\mathbf{a}$ about O_1. The vector $\mathbf{P}$ of the external force acting on m_1 is ahead of $\mathbf{a}$ by an angle φ. The other forces at m_2 are as follows :—

spring force due to k_2 : $\mathbf{S}_{12} = -\mathbf{S}_{21} = k_2\,(\mathbf{a} - \mathbf{b})$,
spring force due to k_1 : $\mathbf{S}_1 = k_1\,\mathbf{a}$,
inertia force : $\mathbf{X}_1 = m_1\,\omega^2\,\mathbf{a}$,
damping force : $\mathbf{D}_1 = c_2\,\omega\,\mathbf{s}_{12} = -\mathbf{D}_2$.

As relative damping has been assumed, the vector $\mathbf{D}_1$ will lag by a phase-angle $\pi/2$ behind $\mathbf{S}_{12}$.

Furthermore, we may replace $\mathbf{S}_{12}$ by $\mathbf{D}_2 + \mathbf{X}_2$, and the equilibrium of forces gives

$$\mathbf{D}_2 + \mathbf{X}_2 + (\mathbf{S}_1 + \mathbf{X}_1 + \mathbf{D}_1) = \mathbf{P}, \text{ so that}$$
$$\mathbf{X}_2 + \mathbf{S}_1 + \mathbf{X}_1 = \mathbf{P}.$$

The influence of the auxiliary system on the main mass

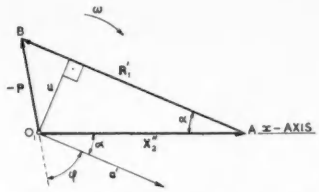


Fig. 3. **Vibration diagram for the main system.**

is represented by the inertia force vector $\mathbf{X}_2$ of mass m_2 acting on mass m_1. (The damping produces only the phase shifts, i.e., the angle α between vectors $\mathbf{a}$ and $\mathbf{b}$, and the angle φ between $\mathbf{a}$ and $\mathbf{P}$). Combining $\mathbf{S}_1$ and $\mathbf{X}_1$, we obtain

$$\mathbf{S}_1 + \mathbf{X}_1 = k_1\,\mathbf{a} - m_1\,\omega^2\,\mathbf{a} = k_1\,\mathbf{a}\,(1 - \nu_1^2) = \mathbf{R}_1$$

where $\nu_1 = \omega/\omega_{n1}$ = frequency ratio of the main system. Thus, there is equilibrium of forces at m_1 when $\mathbf{X}_2 + \mathbf{R}_1 - \mathbf{P} = 0$, i.e., when these forces form a closed triangle. To obtain non-dimensional quantities, we divide all forces by $|\,k_1\,\mathbf{a}\,|$ and the amplitudes by $|\,\mathbf{a}\,|$, so that

$\mathbf{X}_2' = \mathbf{X}_2/(k_1\,a) = m_2\,\omega^2\,\mathbf{b}/(k_1\,a) = (\mathbf{b}/a)\,(k_2/k_1)\,\nu_2^2$,
$\mathbf{R}_1' = \mathbf{R}_1/(k_1\,a) = 1 - \nu_1^2$,
$\mathbf{P}' = \mathbf{P}/(k_1\,a) = \mathbf{a}_s/a = 1/M$,
$\mathbf{a}' = \mathbf{a}/a = 1$ (unit vector in direction of $\mathbf{a}$).

Using these vector quantities, the vibration diagram of Fig. 3 is constructed as follows :—(1) Determine $\mathbf{b}' = \mathbf{b}/a$ from the lengths of $\mathbf{a}$ and $\mathbf{b}$ in Fig. 2. (2) Calculate $\mathbf{X}_2' = (k_2/k_1)\,\nu_2^2\,\mathbf{b}'$ and plot this as a vector $\overrightarrow{\mathbf{OA}}$ along the x-axis. (3) Draw the line of action of $\mathbf{R}_1'$ through point A, with the angle α determined from Fig. 2.

Draw along this line the vector $\mathbf{R}_1' = \overrightarrow{\mathbf{AB}}$ of length $1 - \nu_1^2$. (4) Connect B with O_1. Then $|\,\overrightarrow{O_1B}\,| = |\,-\mathbf{P}'\,| = 1/M$, where $M = a/a_s$ for the given values $\nu_1 = \omega/\omega_{n1}$ and $\nu_2 = \omega/\omega_{n2}$. (5) The value of $|\,\mathbf{a}\,|$ is then $|\,\mathbf{a}\,| = |\,M\,\mathbf{P}/k_1\,|$. Hence, all the vibration amplitudes, forces and phase-angles of the system are fully determined.

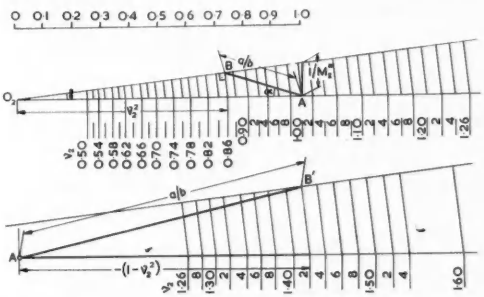


Fig. 4. **Vector diagram of the damper mass m_2 for $\psi = 0{\cdot}75$**

TABLE I.

$k_2/k_1 = 1/20$; $\psi = 0{\cdot}75$; $M_2^\star = 8{\cdot}38$; $1/M_2^\star = 0{\cdot}1195$.

ν_2	ν_2^2	φ / $M_2^\star$	a / b	$k_2\,a\,\nu_2^2$ / $k_1\,b$	$\sigma = 1{\cdot}0$							$\sigma = 0{\cdot}8$		
					ν_1	ν_1^2	$1 - \nu_1^2$	$1/M$	M	u	$M^2\,u$	ν_1	ν_2^2	. . .
0·76	0·58		0·43	0·067			0·42	0·36	2·78	0·007	0·054	0·95	0·90	
0·80	0·64		0·38	0·084			0·36	0·28	3·57	0·018	0·23	1·00	1·00	
0·90	0·81		0·22	0·184			0·19	0·087	11·5	0·08	10·52	1·12	1·25	
0·96	0·92		0·15	0·307			0·08	0·26	3·85	0·23	3·41	1·20	1·44	
1·00	1·00	0·12	0·12	0·417	$= \nu_2$	$= \nu_2^2$	0·00	0·41	2·44	0·41	2·44	1·25	1·56	
1·10	1·21		0·24	0·253			—0·21	0·15	6·67	0·148	6·6	1·37	1·88	
1·20	1·44		0·45	0·160			—0·44	0·30	3·34	0·062	0·69	1·50	2·25	
1·26	1·59		0·60	0·133			—0·59	0·46	2·18	0·045	0·214	1·57	2·46	

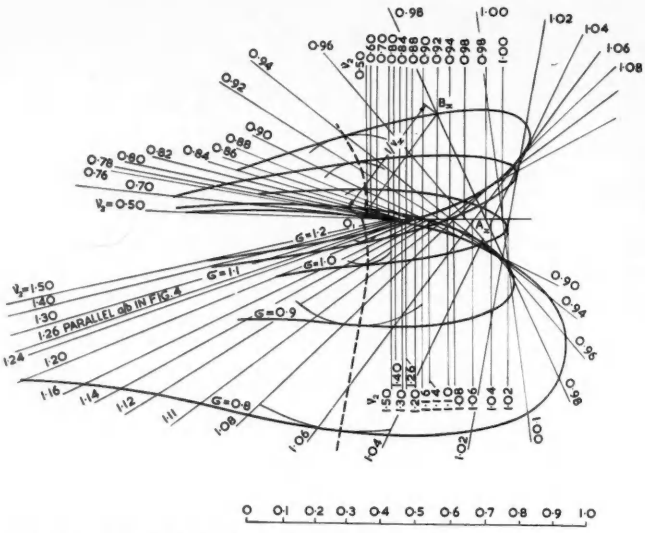


Fig. 5. **Vector diagrams for the main mass m_1 for various tuning ratios σ of the damper and $k_2/k_1 = 1/20$.**

If this simple construction of Fig. 3 is repeated for various values of the frequency ratio ν_1, we obtain a graph of the resonance function $M = M(\nu_1)$ of the two-mass system.

Two further ratios which are useful in damper calculations are :

the tuning ratio : $\sigma = \omega_{n1}/\omega_{n2} = \nu_2/\nu_1$,
and the mass ratio : $\mu = m_2/m_1 = \sigma^2 k_2/k_1$.

EXAMPLE OF APPLICATION

For a two-mass system, with rubber damping in the auxiliary system, it is required to determine the resonance function M graphically, for the following values :—

tuning ratios : $\sigma = 0{\cdot}8,\ 0{\cdot}9,\ 1{\cdot}1,\ 1{\cdot}2$,
stiffness ratios : $k_2/k_1 = 1/20,\ 1/2$.

The damping ratio for rubber is taken as $\psi = 0{\cdot}75$.

The graphical determination is carried out fully for the stiffness ratio $k_2/k_1 = 1/20$, whereas for $k_2/k_1 = 1/2$ only the resonance curves are represented.

We first calculate the constants ν_2 and ${\nu_2}^2$, then for various tuning ratios σ the constants ν_1 and ${\nu_1}^2$ and $1 - {\nu_1}^2$. These values are tabulated (Table I). For $\psi = 0{\cdot}75$, we have the auxiliary-system dynamic magnifier $M_2^{\star} = 2\pi/\psi_2 = 8{\cdot}38$ and $1/M^{\star}_2 = 0{\cdot}1195$.

Thus we are able to draw in Fig. 4 the vector diagrams of the damper mass (i.e., the auxiliary system of Fig. 2) for various ν_2-values. These give the vibration amplitude ratios a/b and the phase-angles α.

The diagrams for the main system (construction of Fig. 3) are based on the calculated values of $(k_2/k_1) \times (b/a) \times {\nu_2}^2$, which are included in the table. Fig. 5 shows the vector triangles of the main mass for various frequency ratios ν_2 and damper tuning ratios σ. With a constant value for the tuning ratio, the points B of the vector triangles (Fig. 3) are situated on a curve. In order to determine the maximum values of the resonance function, we describe circles about O_1 which touch the curve σ = const. under consideration. These points of contact determine the maximum values of the resonance function. These latter values are also situated on characteristic curves for the various tuning ratios of the damper.

By means of the values $\overline{O_1 B} = 1/M$ determined from these vector diagrams, we are able to draw the resonance curves of Fig. 6 as functions of the frequency ratio ν_1. These curves indicate the influence of the mass-ratio and damper tuning. It is seen that the resonance peaks are close together for small values of k_2/k_1. For $k_2/k_1 = 1/2$ and $\sigma = 1$, the peaks are much further apart : $M = 15{\cdot}2$ at $\nu_1 = 0{\cdot}7$ and $M = 4{\cdot}5$ at $\nu_2 = 1{\cdot}42$, that is, in this case the critical frequencies correspond to a ratio of about 1:2. The resonance curves give a clear picture of the relative performance of the various dampers.

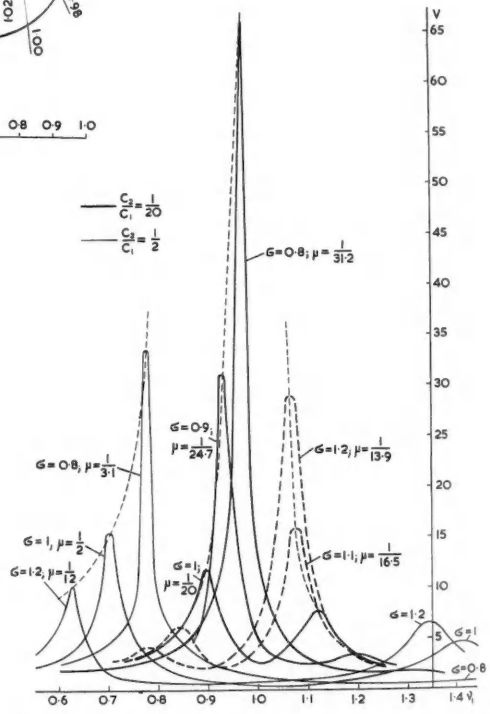


Fig. 6. **Graphically determined resonance curves of the main system fitted with a rubber damper ($\psi = 0{\cdot}75$).**

BIBLIOGRAPHY.

LEHR, E. : Vibration technology (Schwingungstechnik). Vols. 1 and 2, Springer, Berlin, 1930.

FÖPPL, O. : Vibrations in engineering. Vol. 2 : Vibration resonance and damping (Grundzüge der techn. Schwingungslehre, Bd. 2 : Aufschaukelung u. Dämpfung von Schwingungen). Springer, Berlin, 1936, pp. 8, 9 and 36.

STEINBORN, E. : Damping as a measure of the quality of rubber. Communication of Wöhler Institute, Braunschweig, Bulletin No. 31, 1937.

ROELIG, H. : Dynamic use of damping and fatigue strength of vulcanised rubber. Reprint from "Kautschuk," Nos. 1 and 2, 1939.—Damping and elasticity modulus as functions of temperature used as criteria for the elastic behaviour of rubber. Reprint from "Gummi-Zeitung u. Kautschuk," Berlin, June-July, 1943.

ROELIG, H. and HEIDEMANN, W. : Similarity between elastic and dielectric properties of rubber polymers. Reprint from "Kunststoffe," Vol. 38, No. 7.

Workpiece and Surface Temperatures in Milling

By A. O. SCHMIDT. (From paper No. 52-A-86, presented at the Annual Meeting of the *ASME*, November/December 1952, 20 pages, 19 illustrations.)

Recent investigations have shown that metal cutting involves many unique and complex problems of heat flow, temperature distribution, friction, and behaviour of metals. This paper reports mainly the state of workpieces with respect to sensible heat. The temperature gradient in workpieces while being milled and the existence of very high instantaneous surface temperatures during the cut have been determined experimentally.

TEMPERATURE GRADIENT IN WORKPIECE

The main object in the tests reported here was to determine experimentally the maximum temperature occurring in or near the surface of a workpiece while it was being milled. Temperature readings were taken at several different levels in the workpiece as seen in Fig. 1. The test bar had a slot in the centre where the

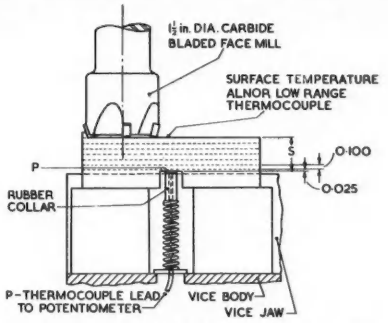


Fig. 1. **Test arrangement for measurement of workpiece temperatures.**

In the determination of maximum surface temperature the cutter was replaced by an oxy-acetylene flame moving over the workpiece at the same feed rate and causing an identical temperature rise at *P*.

thermocouple *P* indicated the temperature as the tool cut through the workpiece material. As was to be expected, the temperatures recorded were highest when the surface being cut was closest to the thermocouple. The general distribution of maximum temperatures in a workpiece during and shortly after machining is illustrated in Fig. 2. For the last cut the thickness of the remaining layer was only 0·025 in., Fig. 1, and the potentiometer used did not respond fast enough to indicate the peak temperatures which were consequently obtained with temperature-indicating crayons. When the distance *S* was 0·125 in. or greater, a time lag always occurred before the maximum temperature was attained.

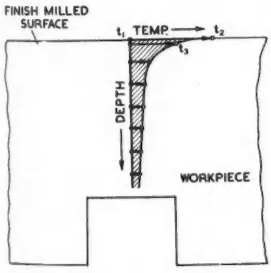


Fig. 2. **Aid to interpretation of charts indicating maximum temperatures attained at and beneath the surface of a milled workpiece.**

The highest temperature reading at *P* during the first cut, for a distance *S* of 0·750 in., was obtained 8 seconds after the tool had finished machining the surface of a steel test bar. As the cutting tool approached closer to *P*, the temperature increase was obtained in a progressively shorter time. Because of better heat conducting properties, these elevated temperatures were reached sooner in non-ferrous materials than they were in steel. When steel test pieces of SAE 1030 were milled at speeds above 400 fpm, blue temper colours were visible on the underside of the 0·025-in. thick layer after the last cut. Therefore, temperatures were high enough and existed for a time sufficient to produce temper colours in the thin sections of the test bar and to change the colours of temperature-indicating crayon marks. The potentiometer responded too slowly at this point to indicate a temperature anywhere near the maximum surface temperature in the workpiece, the temperature gradient being very steep in the shallow subsurface region. Only when the temperatures farther away from the surface were measured was it possible to use this thermocouple equipment with better accuracy, since it took several seconds before the maximum temperature was reached. This meant that an entire section of the workpiece had been heated up. Since a general temperature rise throughout a workpiece is caused by the cutting action, the tool can be considered as a heat source. This heating action of the tool can be reproduced by a heating element adjusted to obtain temperatures in the workpiece similar to those recorded during an actual metal-cutting operation.

In the next series of tests, an oxy-acetylene flame mounted on a carrier which moved at the same feed rates as used in machining was employed to simulate the heat-producing action of a tool. The maximum temperature in Figs. 3 to 7 is the temperature, measured at the workpiece surface, of an oxy-acetylene flame or the gaseous layer beneath it which caused a temperature gradient in the workpiece similar to that produced by the cutting tool. The test bars, $\frac{1}{2} \times 1\frac{1}{2} \times 4$ in., were made of SAE 1090 (170, 311, and 387 Bhn), grey cast iron, free-machining brass, aluminium and magnesium. The three-bladed cutter used for the tests plotted in Figs. 3 to 7 had a 6-deg. negative primary radial rake 0·020 in. wide at the cutting edge of the carbide blades which were placed at a 15-deg. positive radial rake angle in the cutter body. The peripheral clearance angle was 6 deg., the face-relief angle 3 deg., the face-clearance angle 5 deg., and the face-cutting-edge angle 1 deg.

With a test bar $\frac{1}{2}$ in. wide the heat flow was not influenced unduly by the cooler holding devices. Comparative cuts were taken on test specimens of various widths up to 1 in. On test bars wider than $\frac{1}{4}$ in. the temperatures were almost equal, while on those narrower than $\frac{1}{4}$ in., the temperatures were lower because the heat was conducted away at a faster rate by the relatively cold vice jaws.

Workpiece temperatures as recorded when cutting SAE 1030 test bars of 180 Bhn at a cutting speed of 328 fpm are shown in Fig. 3. The solid line indicates the temperature of a test bar $\frac{1}{4}$ in. wide, while the dotted line represents temperatures of a test bar $\frac{7}{8}$ in. wide. The graphs Figs. 4 to 7, are for test bars $\frac{1}{2}$ in. wide.

Test results when milling SAE 1090 test bars of 170, 311, and 387 Bhn under identical conditions, are presented in Fig. 4, each data point plotted being the average of six tests. The highest temperature increases were measured when cutting steel at 387 Bhn. In all the tests shown in Fig. 4, the cutting speed was 590 fpm, and the feed 25 ipm or 0·0055 in. per tooth.

Fig. 5 shows the temperature values obtained at a lower cutting speed of 80 fpm, all other conditions

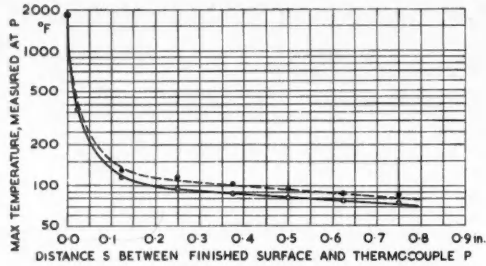


Fig. 3. **Influence of width of workpiece upon maximum surface temperature of SAE 1030 workpiece, 180 Bhn, and temperatures at distance *S*.**
Cutting speed, 328 fpm; feed, 0·0055 in. per tooth. Solid line for workpiece, $\frac{1}{4}$ in. thick, dashed line for $\frac{3}{4}$ in. thickness.

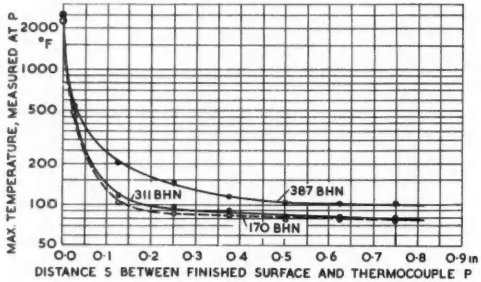


Fig. 4. **Maximum surface temperature of SAE 1090 workpieces of different Brinell hardnesses, and temperatures at distance *S*.**
Cutting speed, 590 fpm; feed, 0·0055 in. per tooth.

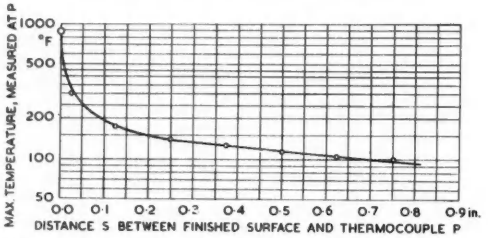


Fig. 5. **Maximum surface temperature of SAE 1090 workpiece, 170 Bhn, and temperatures at distance *S*.**
Cutting speed, 80 fpm; feed, 0·0055 in. per tooth.

being the same as for the tests plotted in Fig. 4. The temperatures obtained indicate that the workpiece heats up much more during the slow cut, because a greater quantity of heat can flow from the shear zone to the workpiece. It should be noted that the workpiece temperature closest to the surface and the indicated maximum surface temperature were, however, much lower than they were at the higher speed. The slow-moving oxy-acetylene flame was mounted some distance away from the workpiece to cause the same temperature rises as the cutter at 80 fpm cutting speed.

The temperature of the workpiece surface can be attributed mainly to the work done or heat evolved in forming the chip from the workpiece. When the tool begins to remove a chip, the metal in the chip and also in a thin layer in the workpiece is deformed simultaneously. This plastic deformation is the largest part of the work required in removing a chip from a workpiece, and most of the work done in a metal-cutting operation occurs therefore as heat in the chip. An additional, but much smaller, source of the heat in the

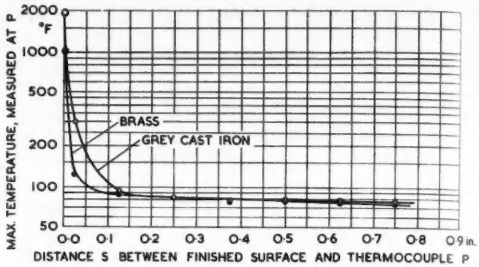


Fig. 6. **Maximum surface temperature of grey cast iron and brass workpieces, and temperatures at distance *S*.**
Cutting speed, 590 fpm; feed, 0·0055 in. per tooth.

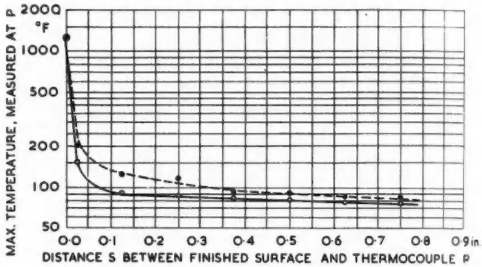


Fig. 7. **Maximum surface temperature of 24-ST A1-alloy workpieces and temperatures at distance S.**
Cutting speed, 590 fpm; feed, 0·0055 in. per tooth. Solid line, sharp cutter; dashed line, dull cutter.

chip is the friction between the tool and chip which occurs as soon as the chip begins to move over the tool. The amount of heat in the chip constitutes, as a rule, between 50 and 75 per cent of the total heat in chip, tool, and workpiece together. The smaller figure of 50 per cent applies to the lower speeds; the heat in the chips increases to 75 per cent at about 200 fpm[1]). At the lower speeds a measurable part of the heat from the shear zone is transferred by conduction to the workpiece, since there is contact for longer periods of time. Less of this happens at higher cutting speeds.

Temperature values as obtained when milling grey cast iron are shown in Fig. 6. The effect of a worn cutter when milling 24-ST aluminium alloy is shown by the dashed line in Fig. 7 in comparison to the temperatures obtained with a sharp cutter as indicated by the solid line. In this case the wear could be considered minor and no difference in the cutting action had been noticed by ordinary observations. Free-machining brass, which has generally lower power requirements, also registered low temperatures in the workpiece as can be seen in Fig. 6. Magnesium alloys are usually exceptionally easy to machine and this was confirmed by correspondingly low values of workpiece temperature measurements, similar to those shown for brass in Fig. 6. Although the maximum surface temperature as plotted for milling magnesium alloys is low in comparison to those for the other materials, it is much higher than the temperature measured near the tip of a lathe tool, machining the same material at a comparable speed and feed[2]).

(To be continued)

BIBLIOGRAPHY

(1) "Distribution of Heat Generated in Drilling," by A. O. SCHMIDT and J. R. ROUBIK, *Trans. ASME*, Vol. 71, No. 3, 1949, pp. 245-252.
The Tool Engineer, Vol. 21, No. 5, pp. 20-23.

(2) "Metal Cutting Temperatures and Tool Wear," by A. O. SCHMIDT, *The Tool Engineer*, Vol. 29, No. 1, July, 1952, pp. 33-35 and No. 2, August, 1952, pp. 51-54.

Recent Developments in the Soviet Machine Tool Industry

By J. MANNIN

In this article the author reverts to the subject of mechanical technology and summarises a number of Soviet reviews dealing with the most recent period in this field. Readers are reminded of the significance of this period within the framework of Soviet industrial development. This introduction is followed by a few remarks on Soviet pronouncements about styling of machine tools and a survey of the present situation as to the development of fully automatic production lines, shops and plant for the manufacture of engineering products. These subjects, on which little has been said in previous articles, will be followed followed in our next issue by a list of new designs and conceptions of machine tools ,small tools, abrasives and measuring equipment.

THE period allotted to the first post-war Five Year Plan in the U.S.S.R. came to an end in 1951. The Soviet planning authorities must be given credit for the speed with which they produced the "Plan" immediately upon the cessation of hostilities. But the more sober pronouncements issued with official blessing make it clear that this period was focussed on reconstruction. At the time of writing, symptoms of internal political tension are visible which, gauging by previous experience are likely to produce repercussions so utterly distasteful that our judgment of facts may forgivably be clouded. It is worthwhile enquiring whether from the engineering observer's vantage point genuine evidence can be gathered about disturbances in the stream of Soviet industrial progress.

In that part of the engineering industry which is concerned with the working of metals by cutting tools we can discover little evidence of recent or impending major disturbances or tensions.

Some technical facts are not economically significant unless supported by statistical knowledge. In these articles we have repeatedly pointed out that showpieces which evoke our admiration can be as misleading in Russia as in Western Europe or the U.S.A. However, other technical facts must be accepted as symptomatic and they may add up to a significant picture of the industry as a whole. Perhaps the strongest impression which emerges from a comparison between the first post-war reconstruction period and the first Five Year Plan is that the real industrial strength an of economy in a state of flux is measured not so much by its tools as by its tool makers. While many tools were destroyed, dislocated, or worn out during the war, the tool makers survived and were able to convert plans into reality with incomparably less chaos and disappointment than the untutored army of workers recruited from the villages in the late twenties and early thirties.

In short, reconstruction in the field which concerns us here was accomplished with a speed and effectiveness which probably surprised the administration. Here we must guard against both over and under-estimation.

Nowhere is this danger more visible than in appraising the significance of the so-called satellite industries. In Eastern Germany the Soviet and German machine tool industries came face to face, and their products were often shown alongside each other at Exhibitions. It is difficult not to be amused by the regimented but faint praise accorded by Eastern German commentators to Soviet products when seen alongside their own. The writer's impression is that the technical judgment of these German commentators is swayed more by certain habits of mind developed in a typical exporting country than by patriotic emotion. No doubt, the East German lathe will sell better in competition with, say, the American but the Russian lathe is probably better for Russia. It must be emphasised again that the bulk of Russian industry was already provided by an indigenous machine tool industry in the late thirties.[1] This covered all the general purpose machine tools of medium size and medium precision. Imported machine tools could only be of value either when adapted to the Russian pattern, for which there was little chance, or as machine tools of exceptional size and exceptional precision, or for exceptional machining tasks.

It is in the category of exceptional size that the satellite deliveries were of real value to Soviet industry. In the more normal categories, Soviet production engineers quite properly realised that the biggest advances in productivity during the period of reconstruction could be achieved by modernisation of existing machines. In this sense, the great enthusiasm for high cutting speeds was truly justified, because modernisation by increased cutting speed is possible and sometimes even easy, whilst modernisation by increased cross-section of cut is usually virtually impossible. Here, as elsewhere, it is necessary to judge Soviet technology in the light of the industrial situation in the U.S.S.R.

The year 1951 bridges the first and second post-war Five Year Plans. The achievements of the two-year period roughly between the middle of 1950 and the middle of 1952 have therefore been the subject of a number of reviews which appeared in the Russian technical press in the second half of 1952. Concurrently, the directives of the Second Five Year Plan are being explained and popularised among Soviet technicians, and several articles have appeared in which the general trends of specific lines of development, such as hydraulic operation or copying devices, are examined. Moreover, some notable original designs have reached the production stage and some Soviet orators speak of the liberation of Russian industry from the yoke of Gleason and Maag almost in the same terms as the William Tell drama, with the apple on the other head.

Among the heart-searching publications, perhaps the least important is the appearance of some discussion on the styling of machine tools which goes under the name of "architectonics," defined as "the organic correlation of parts into a unified whole ; the appropriateness and co-ordination of its parts." If this writer may be permitted an outrageously partisan opinion, the discussion on styling in Russian technical literature is interesting not for the novelty and originality of its approach but for the absence of either.

In Western Europe and particularly in the U.S.A., so-called industrial designers have a tendency to replace sight by foresight. No design is respected unless it is tomorrow's gadget for tomorrow's needs, made with tomorrow's materials and tomorrow's methods. This outlook seems to be at variance with historical experience, which shows that style has always been the result of a delicate balance between function, material and manufacture and could only be achieved in maturity. Presumably, the Western industrial designer is driven by the salesman, for whom everything must be plastic, electronic and, nowadays, atomic.

It is surprising, therefore, to find an identical attitude expressed in Soviet literature. Here is a quotation from an article dealing with the styling of machine tools :

> "The trend points to a complete replacement of geared velocity transformers by those of the all-electrical type controlled by amplidyne electro-mechanical amplifiers."

Few transmission engineers will deny that the amplidyne amplifier renders most ingenious and highly desirable solutions of the electrical drive problems for many types of machinery. However, it is clear from other publications that Soviet engineers are well aware of the fact that an amplidyne controlled motor-generator drive for

individual machine tools is many times more expensive than an ordinary electric motor with a change-speed gear box. The all-electric drive is no more likely to replace more than a tiny fraction of individual machine tool drives, than the all-electric or all-hydraulic transmission has replaced the mechanical gear box in motor cars, in spite of many attempts and theories in the past. Principles of styling which rest on a few exceptional masterpieces of ingenuity, rather than on thoroughly matured, widely employed, and truly versatile elements of construction are the expression of a mood which, in Western Europe at any rate, is more readily associated with the American rhythm of development than with the Soviet approach.

Among the surveys of the Soviet machine tool industry it is symptomatic of the current situation that a really all-embracing review sounds unexciting. The Soviet machine tool industry is already too big and too diverse to grow in a pattern easily recognisable from a bird's eye view. In order to obtain significant information, we have to observe specialised lines of progress.

The last two years have witnessed the conclusion of the development of a number of special-purpose machine tools in such branches of mechanical technology as the manufacture of tractors, locomotives, railway wagons, aircraft and heavy machinery. Machine tools for the machining of pipes and fittings have played a large part in the oil, chemical and metallurgical industries. The last two years have seen the end of the severe shortage of abrasive materials for the tool industry. The foundations for a mounting range of large and high-precision machine tools have been laid. The quantity and diversity of small tools has greatly increased in the last two years ; this applies particularly to the manufacture of c rbide-tipped milling cutters, drills and special-tools. In 1951 the percentage of carbide-tipped small tools in relation to the whole tool output has reached 17 per cent by weight. The total number of types and sizes of machine tools available in 1950 was 670 compared with 500 at the outbreak of the war. Neither the first post-war five-year period nor the last two years have changed the traditional weakness of Soviet manufacturing technology, namely, the dearth of forging machinery of all kinds. Nearly a hundred types and sizes of new machines for various types of hot and cold forging, stamping and pressing have appeared since the war. However, the fundamental weakness has remained and is officially recognised in the provision of the second post-war five-year plan which stipulates an *eight-fold* increase in the capacity of heavy forging presses and similar increases in other types of forging machinery.

Turning now to more detailed studies of separate branches in the machine tool industry, we may begin with that branch of engineering production which has probably received more than its proper share of the limelight, namely, automatic production lines, automatic shops and automatic plants.

Russian spokesmen claim that the automatic plant producing motor car pistons, which was completed by 1950, when it began its preliminary trials before production, has no equal in the whole world. The dream of a wholly automatic factory has never ceased to occupy human minds since the misty origins of fairy tales, and has reappeared in fiction, drama and films in many delectable variations. In such simple processes as the production of manufactured foods (" sausage machines") or chemicals (" untouched by hand "), the dream has been achieved with success and, on the whole, good sense. In many manufactures, total elimination of the human element has an advantage over partial elimination by excluding a source of variability and contamination. The automatic factory in engineering production demands, nevertheless, very different skill and planning.

Even if the Russian claim to absolute originality is no better in this novel development than in many pseudo-historical legends, it cannot be denied that the endeavours of Soviet industry towards the creation of automatic production methods in engineering are advanced and genuine. There is no better evidence of this than the abundance of Soviet sources dealing with the problems, difficulties and limitations of automatic production.

If we disregard for a moment the human implications, much more difficult to foresee in their entirety than many enthusiasts like to believe, the technical differences between making, say, table salt and motor car pistons, both untouched by hand, are most significant. In the first place, the piston requires a very much larger number of operations. Second, the operations upon the piston are of much greater diversity in the type of machinery which their execution needs. Third, it is on the whole easier to achieve the required measure and pattern of uniformity in pistons by allowing an intervention and control by human operators at appropriate times and in an appropriate manner, than by eliminating the human element altogether. Fourth, the class of equipment employed in engineering manufacture is distinguished by its complexity and a combination of influences in its operation which make it prone to random failure. These erratic failures, though they must be, and are, extremely rare, can nevertheless not be wholly excluded. The consequences of an erratic failure are so grave to the economics of production that even the most infrequent breakdowns must be taken into account. It should be understood that random breakdowns are unrelated to regular or otherwise predictable interruptions owing to various forms of wear (such as cutting edge wear) or overheating. These foreseeable interruptions are part of the production plan and enter into the accountancy which determines the productive properties of the whole system.

Soviet engineers realised that the effective design of automatic production works, since it is governed by a multiplicity of operations, delicate control of quality and beset with the need to meet erratic events, could only be mastered with the help of conceptions derived from statistical mathematics. The drive and spirit with which these problems were tackled is illustrated by the fact that in the design and preparation of the automatic piston plan, more than 400 analytical investigations were carried out, some of which have since appeared in the professional press and will receive a closer scrutiny in another article of this series. In several instances, analysis was accompanied by practical endurance testing of units of machinery from which it was endeavoured to derive certain statistical regularities by which random failures can be expressed.

It is also claimed that by the time the major investigation in preparation for the automatic piston plant project was undertaken, enough experience had already been accumulated in the operation of automatic production lines to render regularities derived from shop observation. Soviet engineers have evidently experienced not a few disappointments with the results of automatic work. They are clearly of the opinion that in itself fully automatic operation does not bring economic benefits to engineering production, but only through good planning and good coordination. These are dominated by a large number of factors manifest in all production work such as feeds and speeds, setting-up times, etc. Factors of special importance and posing novel problems are the selection of a number of positions for each section of the automatic line, and quantities needed for internal reserves stored along the lines in transport and in magazines. Soviet specialists insist that only the full coordination of all factors gives the desirable results. It is stressed in particular that a full accountancy of all cost factors must be undertaken and the total production cost used as a minimising criterion for optimum productivity. The full production cost includes, of course, all auxiliary and setting-up times as well as statistically known random losses and the necessary share of the first cost of the automatic line expressed in Russian terminology as the man-hour content of the equipment.

Apart from the balance of productivity, the quality balance must also be met. In machining work, quality is largely identical with dimensional accuracy. Statistical quality control is not a matter of choice but is imposed by the conditions of work in fully automatic machining.

In the beginning of the recent period under review there were already several dozen automatic lines in full production. Alongside the usual Soviet jargon of superlatives, the claims made for these installations are modest. Thus, it is said that " in comparison with non-automatic production, automatic lines have better charactieristics of productivity and production cost. The operator's work on these lines has a larger capacity and is less tiring than his work in ordinary production." Of these four claims, the first three are different words for the same conception, a practice not uncommon among writers on the borderlines of economics in any country. Specific statements can be found on the reduction in the number of operators. Thus, an automatic production line for cylinder heads is served by four operators instead of forty-six required in ordinary production. An automatic production line for gudgeon pins of tractor engines produces an output measured in several hundred pieces per hour and is operated by thirteen workers, instead of the 170 otherwise required. It is difficult to escape the impression that these figures do not betray the exceptional importance attached to savings in man power in the Soviet Union but rather reveal the great need to say something spectacular about every achievement. Since it is not possible to claim with any degree of veracity spectacular improvements in the overall factors of productivity, it is useful to have some partial factors where substantial benefits can be shown. In serious project work we have mentioned that Soviet engineers are guided by overall considerations of cost and quality, and indeed in their pronouncements stress the need to use nothing but comprehensive criteria for the co-ordination of the many factors involved in the design of automatic installations.

During the most recent period, the machine tool works " Ordjonikidze," which specialise in this branch, have created a system of automatic production lines for the machining of cylinder blocks for two different types of generating sets, another line producing cylinder blocks for tractors, and a further system for the machining of cylinder heads. A second machine tool constructor, " Stankokonstrooktziya," has installed a new automatic line for the machining of stepped shafts. Equipment for an automatic line producing gudgeon pins has been completed. Deliveries of machinery have been made for the installation of a second automatic piston factory. This was ordered following some experience with the operation of the first automatic factory for motor car pistons, which has shown an adequate consistency of productivity and quality of product. Automatic production shops for sparking plugs, piston rings and other components are under construction. Project work is proceeding on the design of equipment for the fully automatic production of ball and roller bearings, including their inspection, assembly and packing. Automatic factories for the production of consumer goods like cutlery and razor blades are also in preparation.

Engineering production in the broader sense starts before the machining operations and, thus, the processes forming part of fully automatic manufacture range all the way from casting, forging and welding through various types of heat and surface treatment, machining operations, including turning, milling and grinding as well as boring, drilling and tapping, and finally inspection, assembly and packing. Automatic line equipment includes mechanical handling and storage installation. Naturally, the full list is presented to Russian engineers as a challenge rather than as an immediate programme. In fact, the most urgent development tasks for the near future are considered to be the following :—

(1) Wider development of automatic production of blanks for machining by die-casting, press working, etc.
(2) Development of fully automatic production methods for the manufacture of such typical machine components as sleeves, levers and flanged fittings.
(3) Further development of automatic assembly processes.

Among actual achievements out of the above full list of possibilities, we note the automatic gravity die-casting of non-ferrous motor car pistons which forms part of the automatic piston plant. The melting, pouring, ejection and fettling of the casting are fully automatic. The first plant, though finally successful, required a good deal of production development. The second piston plant will have a completely re-designed automatic casting line.

In the class of forging processes, particular praise is given to a newly developed automatic control of multi-pass rolling.

In the execution of machining operations, as every planning engineer knows, the sequence of operations and, in particular, the choice of reference points, can considerably influence productivity and quality. Naturally, these effects are multiplied many times in automatic production lines. Thus, in the first piston plant the initial references were the annular face of the piston skirt and two special reference holes. This required the intervention of non-automatic machining at the beginning of the machining line. One operator looked after the machining of the annular face carried out on a special semi-automatic lathe, and another placed the components on base plates upon which they travel through the automatic line. Some difficulty was experienced with the trapping of chips inside the piston, and in the second piston plant the internal surface of the piston is taken as the original reference. Both the machining of the annular face and the subsequent setting up on the handling base plate is left to the automatic line, one operator is released and the danger of the trapping of chips is eliminated. This example is given to illustrate the extreme care required in the choice of machining sequences.

Automatic lines for the machining of cylinder blocks and cylinder heads, mainly in cast iron, have brought their own problems and solutions. Soviet engineers have always favoured the method of incorporating standard units in automatic production line layouts. This preference was carried to such a point that unit type equipment and fully automatic lines are often confused. Widening the range of fully automatic production has helped to emphasise the separation. In the, by now, almost classical cylinder head line, modelled in its final results on American automotive practice, Russian engineers were fond of emphasising the originality of a consistent application of standard units. These units, manufactured on some scale in the Soviet Union, include boring, drilling, tapping and milling heads. Experience has shown that the real value of unit type construction lies in reducing the time and cost in the *design*, manufacture and development testing of equipment, and, in the higher reliability of fully developed and thoroughly tested mechanisms. Better reliability enables the installation of automatic lines with a larger number of simultaneous machining operations (hundreds of simultaneously working cutting tools). This lengthening of the continuous, independent line section has been found of great importance in the economics of automatic production.

The increase of time between regrinds for cutting tools without loss of precision is one of the decisive considerations. This task is receiving constant attention by Soviet engineers. The automatic adjustment of cutting edges and boring bars is mentioned among others as a current development.

(*Concluded on page* 90)

RUSSIA

The Casting of Milling Cutters of Grey Cast Iron with Carbide Inserts

By P. V. Paukov. (From *Stanki i Instrument*, No. 4, 1952, pp. 22-24, 2 illustrations.)

Milling cutters made of grey cast iron with cast-in carbide inserts can be made in small and large batches at a fraction of the cost of similar cutters assembled from machined components. Such cutters are not only cheaper but also better on account of the best possible support for the inserts. The author describes in detail the design of moulds and the techniques which ensure good castings and longevity of moulds.

The preparation of carbide plates to serve as inserts in a composite milling cutter with a cast iron body consists in the removal of the oxide surface layer by sand blasting, grinding or chemical descaling. This is followed by plating with copper or brass.

Brass plating is best carried out in the following sequence. The plates are thoroughly cleaned in a 5 per cent solution of common salt and then rinsed in clean water. The brass plating bath consists of two solutions. The first solution is made up of 62·5 grams of copper acetate, 82·0 grams of zinc acetate and 2,500 grams of distilled water. The second solution is made up of 175 gr of potassium cyanide, 125 gr of sodium sulphate, 5 gr of sodium carbonate and 2,500 gr of distilled water. A brass plate is used as an anode. The plating is conducted at a current density of 0·5 amps/dm². When copper plating is used, it is applied directly to the cleaned carbide surface. In both cases the thickness of the plating is about 0·06 mm.

In batch production sand moulds are used, whilst for mass production semi-permanent moulds are economical. In sand casting, channels are led to each insert when the casting is large, or to the bridge between every two inserts in small castings. This channel arrangement ensures good wetting of the inserts by the hot melt and thereby achieves strong adhesion between the insert and the body. The system of gates and risers is so arranged that the initially somewhat cooled-off metal is displaced by hotter metal which follows it and squeezes the cooler metal into the riser.

Metallographic studies show that considerable diffusion takes place at the interface between the cast iron and the carbide.

In order to prevent the carbide plates and the whole casting from cooling too fast, a pouring basin and a ring gate are provided. The casting is cooled together with the mould.

In the casting of large diameter end mills (400-800 mm), the strength of the joint between the body and the plates is improved if the inserts are backed by borax coated copper foils of 0·15-0·20 mm thickness. The purpose of these foils is to take up the difference between the thermal contraction of carbide and of cast iron, and thereby prevent the formation of cracks in the carbide inserts during cooling. This copper foil melts when the cast iron is poured in, and during the cooling and solidification of the cast iron the liquid copper is partly squeezed out. In the finished casting, the layer of copper remaining between the plate and the body is about 0·04 mm. If the relative weight of the carbide inserts is large, in order to melt the copper and ensure a good-quality joint, the melt is poured through the mould until the temperature of the metal coming out of the riser reaches 1100° C. Cutters of less than 400 mm diameter are cast without copper foils.

For the casting of end mills below 130 mm diameter a permanent mould is employed containing a sand core as shown in Fig 1. The metal is poured into the central pouring basin, from which it flows into the ring gate, which, as explained before, has the additional function of preventing excessively fast and uneven cooling. From this ring gate the metal runs down through the runner channels, which are slightly inclined so as to direct the jets of hot metal towards the sand core and prevent fast deterioration of the metallic mould. The metal then proceeds through holes provided in the spigot of the core and thence through a runner in the sand underneath the mould and, finally, collects in a riser cut in the sand bed.

The outer shape of the cutter is formed in the permanent mould made of cast iron. Those surfaces of the cutter which are subsequently machined are formed against the surfaces of the sand cores as shown in the figure. A protective layer of colloidal graphite suspended in oil is brushed on the permanent mould surface. In the casting, a layer of gas is formed between the component and the mould.

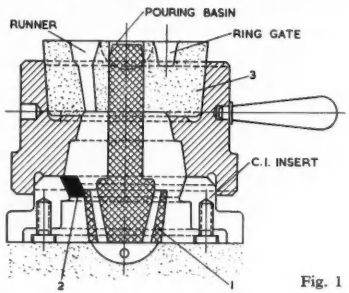


Fig. 1

Before casting, the mould is heated to about 400° C. The cooling of the casting down to about 900° C takes place in the mould. After this the mould is opened and the casting is placed in a furnace with a neutral atmosphere. In the furnace the casting cools down to about 300° C at the rate of about 125° C per hour. Alternatively, after opening the mould, the casting is placed into dry moulding sand enriched with about 20 per cent of ground charcoal. The casting remains so embedded until it is fully cooled down. The time taken for assembling the mould, pouring and withdrawing the casting from the mould is about 10 minutes.

When the mould, either sand or permanent, starts filling up with cast iron, the temperature of the copper-plated carbide insert begins to rise progressively. When the mould is full the copper layer is melted, the pores in the carbide open up, and cast iron penetrates into these pores and creates a tight bond between carbide and cast iron. The copper plating protects the surface of the carbide insert from oxidation during the period of pouring.

The composition of cast iron used for these castings is as follows:— 3·2-3·4 per cent C; 2-2·2 per cent Si; up to 0·9 per cent Mn; 0·2 per cent P; 0·1-0·3 per cent S. This material has a tensile strength of 21-27 kg/mm²; a compressive strength of 40-50 kg/mm² and a Brinell hardness of 179-229. The cast iron is modified in the ladle by means of 0·15 per cent of black graphite. The pouring temperature must not be below 1370° C.

The author claims that the manufacturing cost of a cutter with cast-in inserts is about one-fifth of the cost of making a steel cutter with carbide tips assembled from machined components. It is also claimed that the time between regrinds of cast cutters is multiplied by a factor of between 1·5 and 3. The strong attachment of the carbide inserts means that they can be used up much

(*Concluded on page* 90)

Effect of Low and High Temperatures on Physical Properties and Machinability of Carbon Steels.

By F. BÖGNER. (From *Die Technik*, Vol. 7, No. 11, November 1952, pp. 667-672, 6 illustrations).

Effect of temperature on normal physical characteristics of materials. Effect of temperature on machinability criteria. Analogy between the foregoing effects. Common treatment for chip producing and chipless metal forming. Development possibilities for machining techniques.

THE developments in machining techniques are at present directed towards the solution of two problems :

(1) Increasing cutting speeds for steels above 1000 m/min (3280 fpm) in order to lower machining times and improve surface finish, maintaining acceptable tool life, and operating at relatively low power consumption.

(2) Establishing economical cutting speeds for high-tensile steels of over 100 kg/mm² (63·5 tsi).

Both the above problems necessitate the investigation of all means for facilitating machining. The selection of suitable cutting angles for individual materials and the progressive alteration of these angles with tool wear has led to the development of cylindrically mounted swivelling tools. The improvements in machining through the use of large volumes of coolant refrigerated to 0° to —5° C is another successful development.

The possible beneficial effect of technological changes in the character of the workpiece during machining is yet another possibility of improving machining ; and investigations of this possibility are described below.

The changes in mechanical properties of steel at high or low temperatures have already been investigated. The main criteria of mechanical properties are tensile strength, elongation and impact strength. The highest absolute values of these properties are desirable from the designer's point of view, whereas satisfactory machining demands low values. It should firstly be established whether the values alter in favour of satisfactory machining at any temperatures different from normal. Should positive results be obtained, it remains to be determined whether such changes caused by various temperatures are reflected in the usual machinability criteria. Figure 1 shows characteristic trends of several properties as affected by temperature. The results were obtained from several published papers and are generally valid for all carbon steels. In the case of alloy steels, similar trends apply, but can be influenced by types of alloying elements and heat treatment.

Ultimate strength and yield point decrease with an increase in temperature. The tensile strength of a normal carbon steel passes through a minimum value between 50° and 100° C and through an interim maximum at about 250° C, and thereafter falls steadily with further temperature increases. The yield point has a similar trend, but no clear yield point is discernible from about 300° C. Tensile strength and yield point are to a great extent dependent on the deformation rate at these high temperatures ; a slow rate of deformation has an adverse effect on strength. Elongation and reduction of area show a roughly inverse variation to that of tensile strength. The minimum values of elongation and reduction of area occur at about 150° and 250° C respectively. Carbon steels lose all elasticity at very low temperatures from about —100° C, and fracture under unidirectional loads without elongation or reduction of area. Brittle fractures are also obtained at normal temperatures when the deformation of the material is hindered or prevented by equal, three-directional loading. This brittle zone commences at lower temperatures with alloy steels. Brittle fracture is highly desirable for easy machining, particularly on automatics, as it causes the formation of short chips.

Elongation and reduction of area together are criteria of the " formability " of a material. Good " formability " prevents the formation of cracks at points of high stress, which often occur in metal cutting, and therefore assists in the production of smooth surfaces. The tendency of a material to brittle fracturing is best revealed by an impact test. Impact strength is an indication of the work absorbed to the point of fracture, thus resembling loading conditions as they are present when turning. Beginning at low temperatures of about —40° C, the impact strength passes through a reversal zone at about 0 to 50° C and then falls off steadily at higher temperatures. The " formability " has a minimum value at slow deformation rates and at temperatures between 200° and 300° C, in the zone of blue brittleness. The speed comparisons in the following table show that similar trends apply for impact strength and turning.

Type of test	Energy m/kg	Angular velocity sec^{-1}	Hammer velocity m/min
Charpy	250	129	46
Charpy	75	113	41
Charpy	10	245	29
Frémont	40	806	53
Izod	16·6	157	21
Guillery	60	443	53

Deformation can also be judged from the results graph of a tensile test. The area under the stress-strain curve provides a measure of deformation in the tensile test. There are, however, two conditions which differ for the tensile test and metal cutting. The loading in the tensile test is normally purely in one direction, whereas in turning three-directional loading is usual, i.e., tangential force, radial force and feed force. The rate of deformation is also much lower in the test than it is in turning. According to German standards the loading rate should not exceed 1 kg/cm² sec ; this corresponds to about 0·0005 m/sec or 0·003 m/min (0·12 ipm) for steel of 50 kg/mm² (31·75 tsi). Furthermore, absolute values are considerably influenced by test conditions and are therefore of little use in determining the work in deformation. In order to give some indication of the effect of temperature on deformation, some values obtained from stress-strain curves of softer steels are given in Fig. 1. They show a slight fall at 100° C, a considerable increase at 200° C in the blue brittleness zone, followed by a further fall with a final slight increase at 500° C. It is reasonable to expect blue brittleness to have an effect on the chip formation or quality. The above results, obtained from actual tests, are supported by the following theories.

The character of tensile strength was examined by Orowan, using Becker's theory of crystal plasticity, with the following conclusions. The tendency to fracture without deformation increases at low temperatures and it can therefore be assumed that the decrease in " formability " at low temperatures is greater than the increase in resistance to fracture. This relationship is interpreted as follows, for multiple crystal structures.

The cooling of a metal to low temperatures is equivalent to a reduction of energy. The energy given off by the crystal consists of a static and a kinetic part. The static part is released due to the contraction of the atomic structure, which also involves a reduction of the

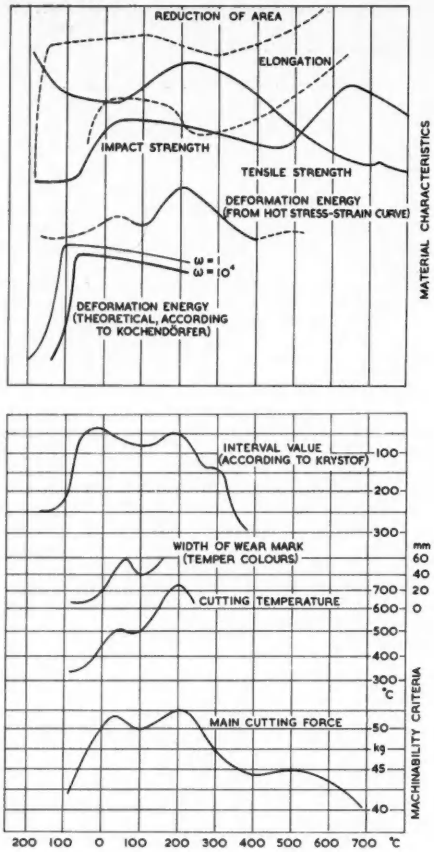


Fig. 1. **Materials and machinability characteristics.**

structure constant. The kinetic part, which is also noticeable as sensible heat, is released due to the decrease of atomic vibration and a simultaneous decrease of vibration amplitude. The contraction of the atomic structure strengthens the attraction between atoms and so results in increased cohesion. The decrease in vibration amplitude, however, increases the energy consumption for the commencement of the translation movement as well as for its continuation. This is due to the fact that the irregularities occurring at the commencement of the translation movement cannot easily vanish with the small atom movement. The cubic centered α-iron shows a similar decrease at low temperatures during boundary slipping, similarly as the hexagonal single crystals. The rate of decrease is, however, higher. The behaviour of low-alloy steels is similar to that of iron. To retain adequate toughness at very low temperatures (—200° to —250° C), it is essential to provide adequate amounts of alloying elements, particularly of nickel, chrome and molybdenum. This ensures a stable austenitic structure, i.e., a cubic face centered structure throughout the entire temperature range. Metals having such a structure behave much more favourably at low temperatures and retain their normal toughness and impact resistance even under arduous conditions. This was investigated and established by Wellinger and Hofmann.

Two types of fracture are possible during the decrease in strength at high temperatures, namely, along the grain boundaries and inter-crystalline fracture. Rosenhain and Ewen and Jeffries have shown that with increasing temperature, grain boundary strength decreases more rapidly than the intercrystalline strength, and that at a certain temperature (equi-cohesion point) they are equal. Grain boundary fractures, which can be regarded as movements of individual atoms, commence at points of stress concentration; during metal cutting they occur constantly at the root of the chip.

Chip formation and the corresponding deformation resistance, however, are influenced not only by temperature but also by speed. The relationship of various material chracteristics, and particularly the relation of deformation to temperature and speed were investigated theoretically by Kochendörfer; the conclusions were then compared with results of practical experiments, as shown in Fig. 1. The illustration shows the strengthening effect with increasing elongation speeds, and the decrease of stress with higher temperatures. The theoretical considerations have correctly shown the trends during stressing and deformation, even though the absolute values may be doubtful owing to the uncertain magnitude of various constants.

It can be deduced from these results that ferrous metals having high "formability" should be machined at high speeds, as the deformation work will thus be reduced. With very tough metals, however, the higher speeds would cause increased shear resistance, and it is therefore preferable to use low speeds and larger chip cross-sections.

The deformation of a chip during metal cutting is a permanent one, and it is therefore desirable to relate the new results of the crystal lattice theory with problems of plasticity. The extension of these considerations from single crystals to multi-crystals was illustrated by Kochendörfer. It must be appreciated that plastic deformation consists of numerous elemental actions, whereas elastic deformation covers the whole lattice. This is further evidence of the doubtful value, as far as metal cutting is concerned, of material characteristics which apply to the elastic range.

The main characteristic of plasticity is its dependence on direction. Slip planes are also noticeable on the cut chip. The crystals of the structure, unfortunately, do not solidify in a definite order, but largely form irregular patterns. If they could be arranged in preferred slip planes, the choice of cutting angles to give minimum cutting resistance would be easy. Only the shear load component is decisive for the slipping action, and this has a definite critical characteristic value for every material. This applies particularly to the commencement of slipping. The most favourable orientation of a slip system occurs when the slip plane and direction of slip are at 45 deg. to the crystal axis. This again is noticeable on the cut chip. Krystof's definition is as follows: "The direction of shear of a continuous chip depends on the angle of friction between the tool face and the chip, since the maximum shear load is at 45 deg. to the direction of the force, the latter being inclined to the tool face by the angle of friction". The changes in the direction of separation of the chip can be ascribed to the changes in friction between the tool face and the chip due to increasing speeds.

Slipping in an ideal lattice would entail an even separation of two adjacent lattice planes. In practice, however, because of imperfections in the lattice structure, the atom displacements are considerably larger. The potential energy during slipping is of a pulsating character owing to the attraction of adjacent atoms. During turning, slipping proceeds in steps and this is reflected in high-frequency fluctuations of the cutting force.

The slip separation force, assuming a constant speed, is a function of temperature, and decreases with higher temperatures. It is logical to expect machinability to change with temperature of the workpiece material, in a

similar manner to the changes in other material characteristics described above. Tests to determine the nature of these changes were carried out on a carbon steel of medium tensile strength (50 to 60 kg/mm²). It is well known that there is no single criterion for machinability. An approximate overall picture can, however, be obtained from the following: Main cutting force, temperature distribution on the cutting edge, tool life, width of the tool wear mark, surface finish and chip formation. Machinability variations were therefore studied, using the following criteria:

(1) Specific cutting force (using the Gottwein-Reichel " thermal force " method and a cutting force dynamometer).
(2) Tool life (wear mark measurement).
(3) Surface finish (planing test after Krystof).
(4) Chip formation when turning and planing.

The test results are shown in Fig. 1, and Fig. 2 illustrates chip formation during turning at various temperatures. The finish of surfaces produced confirm the assumption that machinability is strongly influenced by temperature. This is borne out by changes in main cutting force, cutting temperature, wear and chip formation.

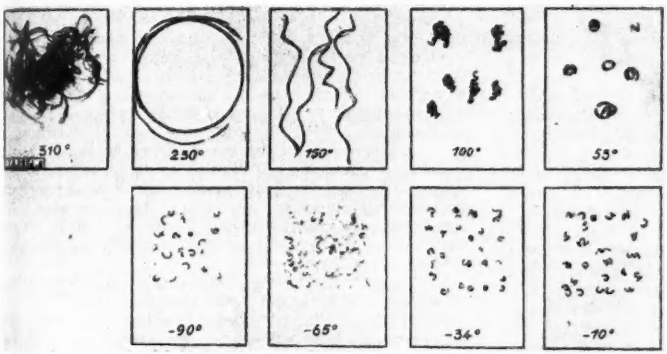


Fig. 2. **Chip formation during turning.**

Chip formation is of considerable importance, particularly on automatic machines, short, brittle chips being preferred. The generally favourable chip formation at high speeds was discussed by Schwerd, and Klopstock investigated the field of chip breakers. The most effective means of improving chip formation is the change of material composition by the addition of phosphorus or sulphur, lead, oxides or selenides with iron or manganese. These additions increase the brittleness of the steel, and the changed characteristic remains with the material. Components made of such materials are therefore unsuitable for heavy stressing. A steel to which could be imparted a " temporary " brittleness, but which would revert to its normal physical properties after machining, would be ideal. This would, in effect, involve a " negative annealing ".

The photographs of chips formed at different temperatures suggest that the steel does become more brittle at low temperatures, from about —60° C, and thus forms the desirable short chips. A similar effect is noticeable with the lower planing speeds at about 230° C, in the region of blue brittleness. The increased brittleness at this temperature is hardly noticeable at the higher turning speeds. One physical characteristic of a metal which may be indicative of chip formation properties is ultimate elongation. The tendency to crack formation, which is associated with increased brittleness, is detrimental, as it results in rough surface finish.

A possible solution of the problem for machining on automatics is the cooling of the workpiece down to about —60° C in a cold bath. It would then have to be thermally insulated on the machine tool, but the increased brittleness would provide the desired short chip. The increase in brittleness would be due to the contraction of the atom structure and the lowering of the atom vibration energy at low temperatures; both these effects would disappear, once the workpiece is allowed to return to ambient temperature.

The physical characteristics of normal carbon steels plotted in Fig. 1 show quite definite trends at various temperature stages, irrespective of absolute values. These can be compared with machinability criteria, such as cutting temperature, width of tool wear mark, and main cutting force, again plotted against material temperature.

Analogy of Cutting Temperature—Physical Characteristics

Reliable conclusions can only be drawn so long as the width of the wear mark remains approximately the same, i.e., in this particular case, between work temperatures of —100° C and 150° C. Reichel also suggests that comparisons should only be made under similar tool life conditions and that the width of wear is one of the tool life criteria. The results clearly show that ultimate tensile strength is not indicative of tool life. This is particularly noticeable between 0° and —100° C, where the tensile strength increases with decreasing temperature, whereas cutting temperature falls. The ultimate reduction of area is also not analogous, as it decreases between 100° and 300° C, contrary to the increase in cutting temperature. There is, however, a distinct similarity in the characteristic decrease of deformation energy from about 100° and 300° C. A clear similarity of trends is shown between cutting temperature and wear, the latter being measured as the width of temper colour bands of similar colour tones.

Cutting Force Measurements

The detrimental effect of increasing tool wear in a wide temperature range could be eliminated in the cutting force tests by using cemented carbides. The trend of the main cutting force thus lends itself better to comparisons with changes in physical characteristics. The increase of cutting force from —100° C to 30° C, however, is quite dissimilar to that of tensile strength. An analogy with reduction of area is again not valid because of the opposite trends from about 300° C upwards. Considerable similarity is revealed between cutting force and deformation energy, measured as the area under the stress-strain curve, when plotted against temperature.

The Planing Test

The planing test is particularly suitable for revealing the " formability " of a material. One of the clearest criteria is the interval value. Its trend with changing temperature partly follows the above-mentioned trends of the measured cutting force, yet there is a similarity with deformation energy, as the influence of speed on planing and tensile test is similar.

It is still questionable whether absolute values of deformation energy, measured as the area under the stress-strain curve, can provide a valid criterion of energy. This is most unlikely, as deformation energy is greatly dependent on loading conditions (largely uni-directional in the tensile test and multi-directional in metal cutting), the shape of the test piece and test speed. Impact resistance is a well-known indication of

deformation energy, but here again test results are dependent on test piece shape and other test conditions.

After having established an analogy between deformation energy and machinability for normal carbon steels in the above investigation, it is of interest to note that Billigman recently obtained similar results in his work on deformation of cold-working steels. This similarity would suggest that a common treatment of these problems for machining and chipless forming is possible. This can be further supported by the fact that both processes are in the region of plastic deformation. The main difference between the two processes can be summed up as follows : The deformation speeds and cross-sections in chipless forming for a given tool life can only be increased just below the breaking strength of the material, whereas in metal cutting these values are taken right up to the breaking strength.

The validity of the analogy is further confirmed by comparing the effect of deformation speed with the above-mentioned theoretical results obtained by Kochendörfer. He found that at higher deformation speeds, material load characteristics were higher, yet values of deformation energy were lower. A clear analogy can be developed from this for machinability, the latter being defined as specific cutting force. Specific cutting force decreases with increasing speeds ; this was proved by the writer up to 2,260 m/min (7,440 fpm). This again suggests a similarity to deformation energy and not to tensile strength.

As a result of the above considerations there emerge two possibilities of improving machining in practice. Firstly, there is the method of cooling the workpiece and, secondly, there is an extension of the " hot machining " method. The latter has already been used for hard and cast steels, and for practical application of this method, values of temperature at which machinability improves should be available. These values could be obtained from tensile tests on hot specimens as given in Fig. 1. For example, a suitable temperature for a 50 kg/mm² steel would be about 400° C.

SUMMARY

Changes in machinability criteria due to changes in material temperature can be proved. Improved machining conditions for cutting difficult steels on automatics are found at temperatures below —60° C and above 400° C. The use of these is advantageous in that materials retain their normal properties and, after machining, their tensile strength is unimpaired. This compares favourably with free-cutting steels developed specially for easy machining on automatics which normally have poor physical properties.

The problem of the relationship between normal physical properties and machinability was further clarified by proving the analogy between machinability and deformation energy obtained from the stress-strain curve. A further development is the possibility of common treatment for problems of machining and chipless forming.

A list of 17 references is given in the original article.—Editor, E.D.

RECENT DEVELOPMENTS IN THE SOVIET MACHINE TOOL INDUSTRY

(*Concluded from page* 85)

The new automatic line for stepped shafts has certain special characteristics. This is a line adapted for re-setting to machine a variety of components, having from two to six stepped diameters, and the machining operations include the finish grinding of precision fillets. The necessary precision can only be achieved by simultaneous grinding of all diameters. Two alternative solutions have been successfully adopted, both, it is claimed, for the first time in the Soviet Union. One is the plunge grinding on a centreless grinding machine with a gang of grinding wheels. The other is the grinding between centres by means of several grinding spindles on unit-built grinding machines. Machines used for these processes will be mentioned in the next instalment of this series.

The discussion of automatic production lines and plants reveals that a number of machining processes, notably gear cutting, have not hitherto attained the productivity necessary for their incorporation in such plants. On the other hand, the development of automatic inspection is proceeding under the guidance of the " Office of Interchangeability." Inspection machines have a wide application and some Soviet designs will be described in the article to follow. At this point it is interesting to record that among the equipment for the automatic production of piston rings, an automatic installation for the inspection of the circumferential clearance in the compressed state is being developed on pneumatic principles. In fact, the sealing capacity of the piston ring is the direct measure of its final acceptance. The fully automatic execution of most heat treatment processes is still in the realm of a development task, so long as it is not possible to complete every such operation within a unit time of a few seconds.

One of the first attempts to accomplish assembly in a fully automatic line, as distinct from a fully mechanised but non-automatic assembly line, has been the pressing of armatures upon the shaft of electric motors, followed by finish turning of the armature. Special attention is devoted currently to the assembly of ball and roller bearings. The technical development has already been successful. On completion of machining, inspection and sorting, the inner and outer races, cages and balls (or rollers) are fed by special handling devices either directly into the assembly automatics or into intermediate storage magazines.

Among the more far-reaching tasks in the engineering of automatic mechanical production, other than the continuous improvement of elements already discussed, the increase in the time between regrinds for turning tools and the manipulation of chips from non-free-cutting steels and metals are emphasised. It is also pointed out that only the development of new production processes, particularly adapted to the rhythm and pattern of fully automatic manufacture, can ensure its maximum benefits. At present, all fully automatic installations for mechanical production are designed and developed by specialist constructors who belong to the machine tool industry. It is foreseen that in future, the production staff responsible for the manufacture of a product will undertake the design and development of these installations, whilst the machine tool industry will confine itself to the creation and manufacture of standard units and the development of fundamental innovations in technological processes.

THE CASTING OF MILLING CUTTERS OF GREY CAST IRON WITH CARBIDE INSERTS

(*Concluded from page* 86)

further than mechanically clamped inserts. The sharpening of cast composite cutters does not differ from that of assembled cutters. After several regrinds the cutter can be restored by the milling of grooves under the cutting edges.

High impact loads may cause pitting or breaking-away of the edges of carbide teeth. To repair the cutter, the damaged carbide plate is removed by melting the cast iron around it with an oxy-acetylene torch and welding a new, copper-plated, carbide insert in its place. After the welding, the cutter is allowed to cool in charcoal powder and the new inserts are ground to shape.

The "Transferometer"—An Apparatus Measuring the Performance of Servomechanism Elements

By P. BONNET. (From *Mesures et Contrôle Industriel*, Vol. 17, No. 187, December, 1952, pp. 691-699, 16 illustrations.)

This article describes an apparatus measuring the gain and phase of servomechanism elements over a range of frequencies from 1/50 to 50 cps. The equipment can be used for d.c. devices as well as for elements with a carrier frequency.

THE transfer function $T(j\omega)$ of a servomechanism element is defined as the ratio S_2/S_1 of the output signal to the input signal. As these are represented by complex numbers, the absolute value of the ratio is $|T(j\omega)| = |S_2| / |S_1|$ and the phase difference is $\angle T(j\omega) = \angle S_2 - \angle S_1$ (where $\angle$ = phase angle).

For a number of elements in series, without feedback, the overall transfer function is the product of the individual $T_k(j\omega)$ — values, giving $|T(j\omega)| = |S_n| / |S_1|$ and $\angle T(j\omega) = \angle S_n - \angle S_1$. If there is a feedback between two elements, for instance between T_D and T_G, then the overall transfer function for the stages in this section is

$$S_G/S_C = T_D T_E T_F T_G/[1 + T_f (T_D T_E T_F T_G)]$$

where T_f is the feedback transfer and S_C the output signal of the element preceding T_D. As logarithms of products give additive terms, it is frequently an advantage to use the logarithm of the transfer function

$$\log_e T(j\omega) = \log_e |T(j\omega)| + j \angle T(j\omega)$$

which separates amplitude values from phase angles and permits additions or subtractions of the results.

For elements governed by linear differential equations, the transfer functions appear as ratios of polynomials with real coefficients. Such transfer functions can always be reduced to products of terms of the first or second degree in $j\omega$, with real coefficients, corresponding to the following forms :—

$$\frac{1}{j\omega + \omega_0}, \quad j\omega + \omega_0, \quad \frac{1}{(j\omega)^2 + 2\zeta\omega_0(j\omega) + \omega_0^2},$$

$$(j\omega)^2 + 2\zeta\omega_0(j\omega) + \omega_0^2,$$

where ω_0 is the resonance value of frequency and ζ the relative damping.

Charts are available [1] which give the amplitude and phase values of the logarithms of these expressions as functions of log ω. These charts simplify considerably the computation work.

This brief survey indicates the importance of transfer functions in the analysis and synthesis of servomechanisms. Although the theory requires a fairly high level of mathematics, these transfer functions represent simple physical characteristics.

NECESSITY OF A MEASURING APPARATUS

Servomechanism transfer functions can be calculated from the characteristics of the electrical or mechanical elements considered (impedances, valve gains, moments of inertia, viscous friction, etc.). However, the error in each of these values results in an overall error in the calculated value of the transfer function. The inaccuracy is increased by three further sources of error, viz. :—

(1) parasitic feedback between elements ;
(2) oversimplified theory of the physical system, particularly at high frequencies ;
(3) non-linear effective behaviour of system.

Errors due to undesired feedback can be eliminated by careful arrangement of the components. As an example of (2), we have the two-phase induction motor with a control winding, which is represented by a transfer function with one or two time-constants, according to the theory used. Errors of type (3) invalidate the analysis which is based on a linear theory. Non-linearity can be produced by backlash, friction, saturation, hysteresis, etc., and is not easily eliminated. However, in most cases, it is found that it can be reduced by designing the power stages as selective elements so as to filter out the harmonics produced by previous non-linear elements. This method has been successfully applied in France and the United States [2].

The above considerations indicate the importance of measurements for determining the transfer functions of individual elements or groups of elements. In fully assembled servomechanisms, further measurements are needed to verify that there are no disturbing feedbacks between stages.

An interesting test procedure has been developed by the Société d'Electrotechnique et d'Automatisme. A phase-shift network and an amplifier with a zero time-constant, both adjustable according to requirements, are connected to the network to be investigated so as to form a closed loop. With the phase control unit, an additional phase shift is introduced, and the logarithmic gain of the amplifier is then adjusted so that the system will just begin to oscillate. The gain and phase margin of the controlling system are then $-g$ and φ, respectively, at a frequency very close to the oscillation frequency. This procedure enables systems to be studied under actual operating conditions, but it is applicable only to complete servomechanisms and not to individual stages. It will thus be a distinct advantage to have an apparatus designed for gain and phase measurements on servomechanism elements, which will be sufficiently versatile to apply to various mechanical, hydraulic, electrical and other processes.

Although some types of transfer measuring equipment have been developed in other countries, they were not available in France, and it was therefore decided that the Central Armaments Laboratory should design and produce a suitable apparatus. This is described below. The development work on the "Transferometer" was carried out with the collaboration of Messrs. Pfiffner and Landrin.

PRINCIPLE OF THE "TRANSFEROMETER"

The apparatus permits a point-by-point determination to be made of the phase locus and the curve of logarithmic gain (in decibels) of transfer functions. The apparatus is of the null-balance type.

A variable-frequency sine-wave generator G supplies signal voltages through output channels 1 and 2, as shown in Fig. 1. Channel 1 passes through a phase control unit, adjustable over 360 degrees, and is connected to the horizontal plates of an oscilloscope O. Channel 2 passes through an adjustable attenuator A_1 and acts on

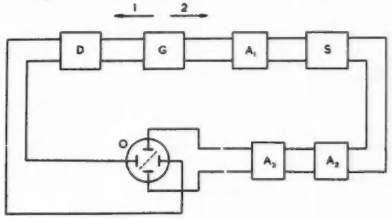


Fig. 1

the servomechanism element S which is under investigation. At the exit of S, the signal passes through an adjustable attenuator A_2 and an amplifier A_3, which is connected to the vertical plates of the oscilloscope.

After choosing a value for frequency, the attenuator A_1 is adjusted so that the input level of the signal at S will have a suitable value. When stable conditions are reached, the attenuator A_2 and the phase-shift unit D are adjusted to obtain a line at 45 degrees on the oscilloscope screen. If φ = phase shift due to D ; a_1, a_2 = logarithmic attenuations of A_1 and A_2, respectively ; and g = logarithmic gain of A_3 ; the phase Φ and the logarithmic gain G of the element S are determined as

$$\Phi = \angle\, T(j\omega) = \varphi$$
$$G = \log_e \mid T(j\omega) \mid = a_1 + a_2 - g.$$

By means of this procedure, it is possible to determine point by point the curves for $\angle\, T(j\omega)$ and $\log_e \mid T(j\omega) \mid$.

It was decided that it would be unnecessary to provide for direct recording to the loci, since the frequencies studied are often below 1 cps and therefore the time taken to plot the points on a graph is negligible compared with the time required to obtain steady-state indications.

The phase shifter is marked in degrees, the attenuator is in decibels and the generator has a frequency scale graduated in octaves, covering a range from about 1/50 to 50 cps. The apparatus can be used for servomechanisms with a carrier frequency as well as for systems with continuous current.

DESCRIPTION OF APPARATUS

Sine-wave generator. In view of the range of frequencies to be covered, it was not possible to consider the use of electromagnetic generators, which cannot operate at low frequencies, or rotary potentiometers, which cannot easily exceed speeds of about 10 rps. An attempt with a potentiometric generator using a dynamo-type commutator, with laminations connected to resistances so as to obtain a sinusoidal voltage distribution, had to be abandoned because of the difficulty of finding a commutator with a sufficiently large number of laminations to give adequate signals at low frequencies.

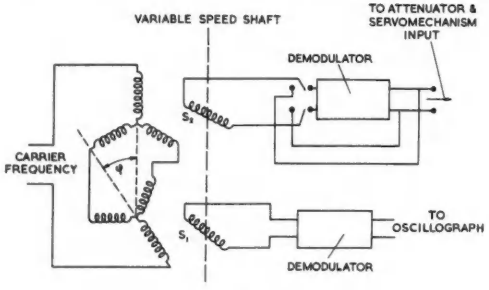


Fig. 2

The signal generator finally adopted is shown in Fig. 2. It comprises two selsyns S_1 and S_2 driven by a variable speed shaft. The selsyn stators are supplied with a carrier current and the connections are such that the alternating stator field has a fixed direction relative to the casing. The voltage obtained at the rotor terminals of each selsyn unit is thus modulated with the frequency of the driving shaft. Its phase can be altered by varying the angular position of the stator of S_1, which can be rotated on its frame through 360 degrees. The phase of S_1 relative to S_2 is indicated on a graduated scale. The output signal of S_1 is demodulated and applied to the horizontal plates of the oscilloscope. The signal S_2 is passed through the attenuator A_1, with or without previous demodulation, according to the type of servomechanism to which it will be applied. For d.c. servomechanisms, the carrier frequency is supplied by a 400 cps oscillator included in the apparatus, and the signal S_2 is demodulated before passing through A_1. If the servomechanism considered operates at 50 cps, the carrier frequency is obtained from a small transformer connected to the mains and the signal S_2 is not demodulated.

Servomechanisms with a carrier frequency differing from the mains frequency always have their own oscillator unit for this frequency, so that this can be supplied also to the testing equipment. In fact, it is often necessary to maintain the signal at a fixed reference value relative to the servomechanism carrier frequency (for instance, in the case of a two-phase motor with a control winding, which has a secondary directly supplied from the carrier frequency source). Here again, the signal S_2 is not demodulated. Furthermore, a servomechanism element can also be tested with any carrier frequency, connecting the test apparatus to a variable frequency oscillator. This also allows the effect of drift in carrier frequency to be investigated.

The selsyns were not initially designed for a speed of 60 rps. At this speed, it was found that there was rapid wear of the metal blade contacting elements rubbing on the slip-rings. By replacing these blades by carbon contacts, satisfactory operation was obtained at all required speeds. The modulation frequency is provided by a controllable-speed motor with a nominal speed of 3000 rpm which can be raised to 3600 rpm. The selsyns are driven by it through a gearbox with three reduction ratios, viz., 1/1, 1/16 and 1/256. The motor speed is indicated in cycles per second on a voltmeter fitted on the tachometric generator of the control unit. Thus, frequency adjustment is possible over the ranges of 4 octaves from 0·015 to 60 cps.

Control of the drive motor. The drive motor is a series-wound d.c. motor of 0·1 hp, fed by two thyratrons θ_1 and θ_2 in a push-pull arrangement, as shown in Fig 3. It drives a tachometer generator, the voltage of which is in opposition to the reference voltage supplied through the potentiometer P_1. The difference voltage is applied after filtering to the grid of amplifier valve (1) and is then taken to the sliding contact of potentiometer P_2. Valves (2) and (3) are part of the stabilising network including the 300 kΩ and 50 kΩ resistances and a 0·25 μF condenser. The voltage from the cathode of valve (4) is applied to the mid-point of the secondary of transformer T which supplies the grids of the thyratrons with an alternating voltage having a 90-degree phase lag relative to the anode voltage. The phase shift is obtained by means of the network R. The thyratrons are thus controlled by a grid voltage due to superposition of this alternating voltage V_A on the continuous voltage V_C proportional to the error voltage. With this standard circuit, it is possible to vary the ignition angle of the thyratrons from 0 to 180 degrees by varying the d.c. component V_C from $+ V_A$ to $- V_A$.

As the reference voltage is negative, the direction of motor rotation is chosen so that the voltage of the tachometer generator will have the polarity indicated in Fig. 3. If the motor speed is too high, the grid voltage of valve (1) rises and the value of V_C is reduced. This has the effect of reducing the mean value of the voltage supplied by the thyratrons and thus lowers the motor speed. If the motor speed is too low, the value of V_C increases. The motor speed thus reaches a stable value, with the reference voltage equal and opposite to the voltage of the tachometer generator. This speed can be varied by an adjustment of the potentiometer P_1.

Valve (2) operates as a safety device. Its grid has a negative bias and normally it does not pass any current. The cathode is at the potential of the field end of the motor. If the motor current is too high, the ohmic voltage drop in the field reduces the cathode potential to

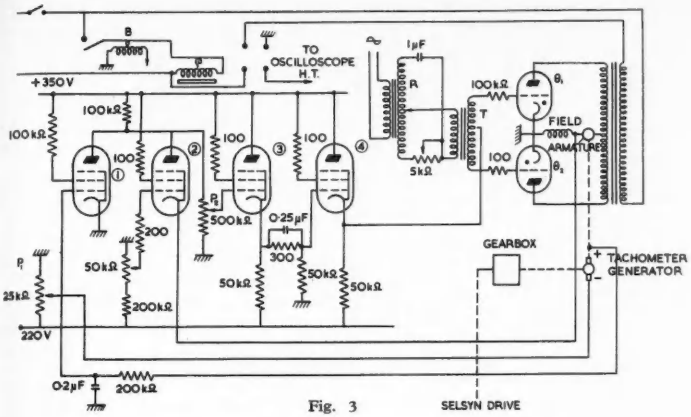


Fig. 3

a sufficiently negative value for the valve to allow current flow through the 100 kΩ resistance which acts on valve (1). This has the effect of lowering the value of V_C and reducing the motor current. The relay and the two-blade contact B delay the application of voltage on the thyratrons and the oscilloscope during the warming-up period of the valves.

Attenuators. A schematic circuit diagram of the attenuators is given in Fig. 4. Each comprises two logarithmic potentiometers of 35 kΩ and 350 Ω mounted on a common shaft. The circuit allows an attenuation of 80 db (from 1 to 0·0001) to be obtained. One complete shaft rotation gives 20 db attenuation, and there are four range positions giving attenuation levels of zero, 20, 40 and 60 db. As the input and output impedances of these attenuators are not constant, they are arranged between cathodyne stages which also serve for impedance matching of the servomechanism element. The valve grid circuits include 3-V batteries which compensate for the d.c. potential difference between grid and cathode and ensure that the signal acting on the servomechanism and d.c. amplifier input has a zero d.c. component. Accurate adjustment is obtained by varying the load on the cathode with a 50 kΩ potentiometer. Output terminals are provided at the cathodes to verify that zero grid polarisation also corresponds to zero at the cathode, and this adjustment is easily made before each test. Between the servomechanism output and the attenuator A_2 a demodulator stage is provided, which can be switched in if the servomechanism has a carrier frequency.

D.C. amplifier. The circuit diagram of this two-stage d.c. amplifier is given in Fig. 5. It has an overall gain of 2000, i.e., 66 db, and acts symmetrically on the vertical plates of the oscilloscope.

General arrangement. The apparatus consists of three units, viz. : (1) the motor control circuit, (2) the internal carrier-frequency oscillator and the demodulator circuits, and (3) the attenuator and d.c. amplifier circuits.

The internal oscillator can be switched out of circuit if an external carrier frequency is used. There are three demodulators. The first is always in operation and feeds the horizontal sweep of the oscilloscope. The other two are switched in if the servomechanism is at carrier frequency. A pentode and a transformer make it possible to superimpose on the sine-wave modulated signal a constant-amplitude signal for the study of servomechanism behaviour when the mean value of the signal is not zero.

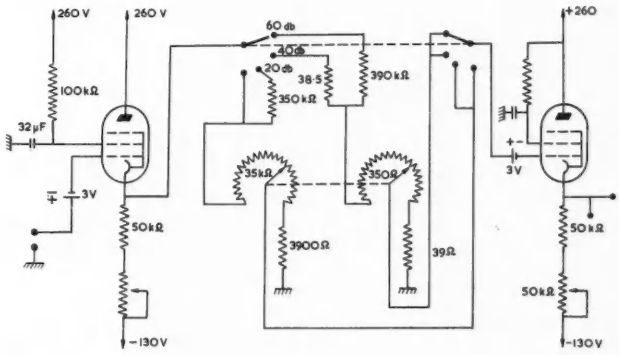


Fig. 4

The circuit of attenuator A_1 also includes two valves providing positive and negative voltages adjustable from zero to 130 V, which are frequently required for the adjustment of servomechanism input levels.

USE OF APPARATUS

The "transferometer" can be used directly for servomechanism elements with input and output quantities which are electrical voltages (i.e., for amplifiers, correcting networks, power generators, etc.). However, it is frequently necessary to determine the

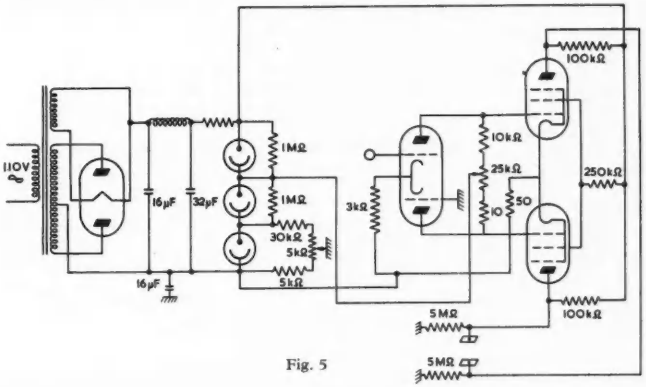


Fig. 5

transfer function of elements operating with non-electrical quantities. For this purpose, the gearbox controlling the selsyns comprises an additional driving shaft, which can be connected to a crank and connecting-rod arrangement producing a reciprocating movement of adjustable amplitude. The 0·1 hp drive motor has sufficient power to drive the input shafts of most servo-mechanisms, which always operate with a low power input.

In many cases, it is necessary to obtain sinusoidal motion having a very small amplitude of the order of some microns (for instance, for reproduction by tracer mechanisms). For this purpose and in order to avoid disturbing backlash effects due to transmission shafts, a special driving arrangement has been developed. It consists of a connecting rod with a scotch yoke at one end of a flexible blade (denoted by E in Fig. 6), which is clamped at the other end. The amplitude of motion at E is appreciable and the backlash is negligible. The amplitude of motion decreases towards the clamped end and in its neighbourhood a sine motion with an amplitude of a few microns can be obtained.

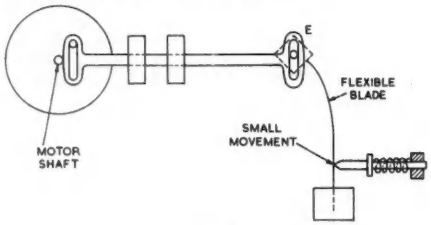


Fig. 6

The conversion of mechanical output quantities into electrical voltages is effected by means of linear or rotary potentiometers for positional quantities, or by tachometer generators and velocity-sensitive devices for speed measurements, etc. These auxiliary drives must have very low resisting torques and inertias in order to avoid introducing disturbances in the transfer function which is to be measured.

It should be noted that, with positional control units, it is frequently fairly difficult to measure the open-loop transfer function owing to the inevitable drift. In such cases, if the back-lash is small, it is preferable to measure the speed of the output shaft by means of a potentiometer, since the drift in velocity is much smaller. This gives the transfer function T_V between speed and the input quantity. The transfer function T_P relating position to the input quantity is then obtainable by integrating T_V, that is, by increasing all the slopes of T_V by 6 db per octave and adding a 90 deg. phase shift to $\angle T_V$. Provided that backlash effects are negligible, there is no risk of error in this determination of T_P, since position is in effect the integral of velocity.

Another method of drift correction consists in attaching to the shaft a spiral spring connected to the frame, so as to obtain a weak restoring torque. If the drift is an absolutely constant effect, stabilisation occurs about a position at which the mean value of the restoring torque is equal to the mean torque causing the drift. The transfer function is disturbed by the restoring torque, but this can be put right by means of a simple correction, which is obtained as follows :—

The actual measurement gives the transfer function between the angle θ of the output shaft and a quantity x (see Fig. 7). This shaft is associated with a moment of inertia $\mathcal{J}$ and a viscous friction coefficient f. It is assumed that the transfer function $\mu\ (j\omega)$ between x and the torque Γ is not accurately known. The measurement gives the value of a transfer function $T_1\ (j\omega)$ which complies with the relation

$$T_1\ (j\omega) = \mu\ (j\omega)/[\mathcal{J}\ (j\omega)^2 + f\ (j\omega) + C].$$

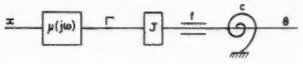


Fig. 7

If there were no restoring torque, the transfer would be

$$T\ (j\omega) = \mu\ (j\omega)/[\mathcal{J}\ (j\omega)^2 + f\ (j\omega)],$$

which is the function we seek to determine. Its value can easily be obtained from that of $T_1\ (j\omega)$ by means of the simple relation :

$$T\ (j\omega) = T_1\ (j\omega)\left[1 + \frac{C}{\mathcal{J}\ (j\omega)^2 = f\ (j\omega)}\right].$$

If C, $\mathcal{J}$ and f are known, we can obtain the expression in the brackets directly, by means of Black's nomogram, and thereafter the value of $T\ (j\omega)$.

Generally, $\mathcal{J}$ and C are accurate values, but f is not accurately known. For this reason, it is an advantage to use a small value for the restoring torque, in order to obtain a small correction for which a fairly large error is still acceptable.

Another method consists in taking two measurements T_1' and T_1'' for $T_1\ (j\omega)$, using two springs of different stiffnesses c' and c''. Then f can be determined from

$$T_1'\left[1 + \frac{c'}{\mathcal{J}\ (j\omega)^2 + f\ (j\omega)}\right] =$$

$$T_1''\left[1 + \frac{c''}{\mathcal{J}\ (j\omega)^2 + f\ (j\omega)}\right].$$

As f is a constant, it is unnecessary to determine the complete curves of $T_1'\ (j\omega)$ and $T_1''\ (j\omega)$, and it is sufficient to take measurements for a single value of ω.

BIBLIOGRAPHY

(1) NASLIN : Mesures & Contrôle Industriel, March-December, 1951 ; also by this author : Les systèmes asservis (Automatic control systems), published by Revue d'Optique.

(2) DUTILH : Theory of non-linear servomechanisms. *La Radio Française*, May, 1950.—KOCHENBURGER : A frequency method for analysing and synthesizing contactor servos. *Trans. I.E.E.*, Vol. 9, 1950.—LOEB : Hereditary phenomena in servomechanisms ; a general stability criterion. *Annales de Télécommunications*, Vol. 6, No. 12, 1951.

Rubber and Leather Bonded to Die Castings for Oil Seals

The Chicago Rawhide Mfg. Co., 1315, Elston Ave., Chicago 22, uses three general methods of bonding rubber and leather to zinc die castings.

For the first type, the zinc die casting is made with a series of steps which act as an anchoring means for the synthetic rubber. A steel centre ring, a rubber preform and the die castings are assembled on a jig and the entire assembly is then subjected to heat and pressure. Thus, the rubber is softened and pressed into place. It is permanently bonded, after curing, to both the zinc and the steel. Here, pressure tightness is not a problem ; the metal and the rubber need only be tight enough to prevent leakage of oil and grease.

In the second type, the advantages of die casting are more fully utilised, as all elements for spacing, mounting and aligning are integral with the die casting. Assembly is the only step needed after the parts are delivered from the foundry.

In a third type of bonding, the seal is cemented to a leather ring. The cement used is known as " Epon " cement, and was developed by the Shell Oil Co. To ensure a good bond between the metal and the leather, the casting is given a chromate surface finishing treatment.

The Correct Dimensioning of 3-phase Motors

By H. C. J. DE JONG. (From *Elektrotechnik und Maschinenbau*, Vol. 70, No. 1, January 1953, pp. 11-15, 4 illustrations.)

The influence of the length/diameter ratio of rotors on the performance of motors is investigated. Formulae are deduced, from which the value of this ratio can be determined for optimum leakage factor and efficiency. The results of calculations are shown in graphical form, and it is demonstrated that "long" designs are advantageous from the point of view of overload capacity, power factor and overall efficiency.

THE LENGTH/DIAMETER RATIO OF ROTORS IN THEORY AND PRACTICE.

Textbooks on the design of asynchronous 3-phase motors give the following formula for the main dimensions of the rotor :

$$P/n = c' D_r^2 L_i \quad .. \quad .. \quad (1)$$

where P = power, n = number of revolutions, c' = output coefficient, D_r = rotor diameter, L_i = ideal length of armature. If c' is known from experiment, D_r and L_i can be calculated, provided their ratio is known.

The indeterminateness of eq. (1), and hence the variability of the factor c', is generally known. It is proposed here to rearrange the equation, so as to gain more information on the L_i/D_r ratio.

Theoretical investigations of the influence of this ratio on the losses, weight and cost of production have been made by Arnold and la Cour.[1] More recent textbooks give values for this ratio which have proved useful in practice.

Closer inspection of practical designs shows that, over the last 50 years, each manufacturer has standardised his motor dimensions, based on a numerical series relating the outer stator core diameter D_a to a corresponding length L of the armature.

Although normally several different values of L are used in practice with each value of D_a (for reasons of economy in stamping tools, pattern storage, etc.), we can still refer to the ratio L/D_a by considering an average value of L. For a given number of poles, D_r can be assumed to be proportional to D_a. L_i is also practically proportional to L. Thus, an investigation of the ratio L/D_a is equally suitable for our purposes.

A new investigation into the most favourable ratio L/D_a appears necessary, as the methods of Arnold must now be considered out-of-date. A more recent work[2] discusses this problem on the basis of Trapeznikow's treatment of a single pole ; its conclusions, however, appear doubtful, as this approach cannot take into account the influence of the diameter on the length of the air gap, depth of slot, etc., and hence does not yield data for the calculation of the optimum length. The problem of the optimum L/D_a relation is topical, as the general European practice is to build motors relatively longer than in the U.S.A., and this practice has recently been criticised[3], unjustly in the author's opinion.

In this article, the ratio L/D_a will be determined which yields an optimum power factor, overload capacity and efficiency. The formulae will be applied to a series of squirrel-cage motors. In the following the index a will be omitted.

THE DIMENSIONING EQUATION.

The knowledge of two relations, valid for a motor type series of given pole number and mode of protection, is required to establish the most favourable L/D ratio with respect to a given electrical property. These are :

(1) The relation between output and the main dimensions,
(2) the relation between the given property and the main dimensions.

The first relation is the equation already discussed, which we now write in a more general form :

$$P = c\, D^x L^y \quad .. \quad .. \quad (2)$$

In this equation the influence of speed is included in the constant c. The exponents x and y are to be determined so that c becomes, in fact, a constant for the given motor type. Its magnitude depends on the mode of protection, e.g., for drip-proof motors the sum of $x + y$ is greater than 3, as the increase of the "constant" c in eq. (1) is included, while y itself is less than 1, as the cooling of the coil ends has comparatively less influence on longer motors.

THE LEAKAGE FACTOR.

The total leakage from stator and rotor will be considered as the sum of three factors : the differential leakage, the slot leakage and the end leakage.

If (1) the effective width of the air gap is proportional to D, (2) the length of the coil ends is also proportional to D, (3) the magnetic flux in the slots per cm of iron length is independent of the dimensions, (4) the magnetic flux in the winding per cm winding length is independent of the dimensions and (5) the number of slots is proportional to $\sqrt{D}$, then the total leakage factor τ can be written as

$$\tau = oD^{-1} + nD^{-1/2} + sDL^{-1} \quad .. \quad (3)$$

the three terms representing the three contributory factors. The constants o, n and s are dependent on constructional data and the number of poles.

It may be assumed that the above five proportionality laws are valid for drip-proof motors, with only small deviations. Law 5, indeed, has already been shown by the author to hold for well-designed squirrel-cage motors.

To show that the total leakage factor can be written in the form of eq. (3), the reactances of the main field, the magnetic leakage field, the slot leakage field and the end leakage field are considered. On applying the five proportionality conditions, and dividing each leakage reactance by the reactance of the main field, we get the contribution of each type of leakage to the total in the form of eq. (3).

From eq. (3) it follows that the ratio L/D will have an optimum value for which the leakage factor is at a

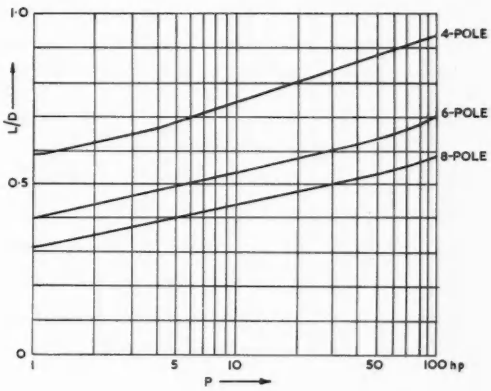


Fig. 1

minimum. Eliminating L from eq. (3) with the aid of eq. (2), and differentiating the resultant expression with respect to D, the following conditions apply for minimum leakage :

$$-oD^{-2} - \frac{n}{2} D^{-3/2} + \left(\frac{x}{y} + 1\right) s \left(\frac{c}{P}\right)^{1/y} D^{x/y} = 0 \quad (4)$$

When o, n, s, c, x, and y are known, the relation between L, D and P can be calculated. Fig. 1 shows the results of this calculation performed on a series of drip-proof current displacement motors with 4, 6 and 8 poles. The optimum L/D ratio is given as a function of the output.

It will be noted that for a given number of poles the optimum ratio L/D increases with increasing output. Also, for a given output, the optimum ratio depends on the number of poles. However, it is not usually practicable to reduce the L/D ratio with an increasing number of poles, as normally this ratio would be kept constant for all pole numbers, to enable the same housing to be used. Hence a compromise must be made.

It is desirable to investigate to what extent it is possible to depart from the optimum value of L/D without appreciably increasing the leakage factor. From eq. (2) we find

$$\frac{L}{D} = \left(\frac{P}{c}\right)^{1/y} D^{-x/(y-1)} \quad \ldots \quad \ldots \quad (5)$$

The above relation between L/D and D for constant output P and given values of c, x and y is represented by curve (1) in Fig. 2. Curve (2) gives the relation of the same two quantities, but calculated for the minimum value of τ. The intersection of the two curves gives the optimum dimensions. Calculating L/D for other values of D, and the corresponding leakage factor yields curve (3). It will be seen that τ changes on the average by only 0·0035, and the corresponding power factor $(\cos \varphi)_{max} \simeq \frac{1}{1 + 2\tau}$ by only 0·005 when the ratio is made twice or half as large as the optimum value. Such a deviation from the best value can therefore be permitted.

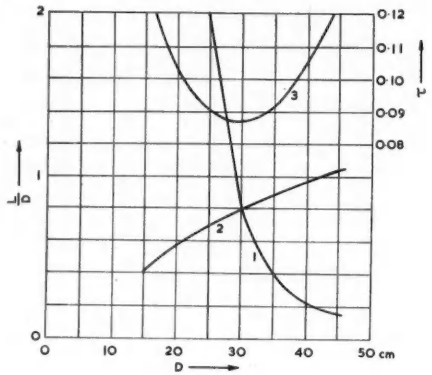


Fig 2

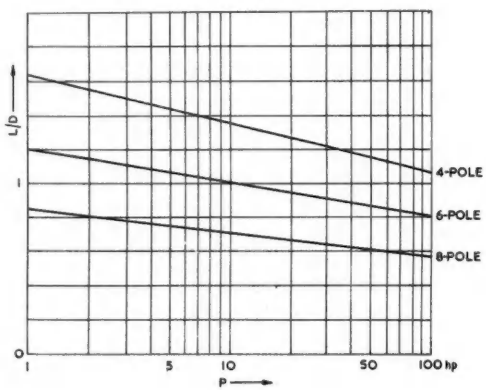


Fig. 3

Overall Efficiency.

To obtain a relation between the maximum efficiency and the ratio L/D, we must know the relationship of the losses to the main dimensions. The losses of a squirrel-cage 3-phase motor, chiefly copper, iron and frictional losses, however, depend on the dimensions in a far more complicated fashion than the constituent terms of the leakage factor (eq. 3). Nevertheless, an approximate relation can be derived, obeying a simple law, by the following consideration :

Let the losses be put into two groups, one of which depends on both diameter and length, the other on the diameter only. To the first group belong the copper losses in the slots, the iron losses and partly the ventilation losses. Copper losses in the stator coil ends and in the rotor short-circuiting rings as well as friction losses belong to the second group. Then the loss factor V can be written as

$$V = v_1 D^{\alpha} L^{\beta} + v_2 D^{\gamma} \quad \ldots \quad \ldots \quad (6)$$

Eliminating L again between eqs. (2) and (6), and differentiating gives the following expression for the optimum L/D ratio :

$$\left(\frac{L}{D}\right)^{\beta} = \frac{\gamma}{x\,\beta/y - \alpha} \frac{v_2}{v_1} D^{\gamma-\alpha-\beta} \quad \ldots \quad (7)$$

When v_1, v_2, α, β, γ, x and y are known, the relation between L, D and P can again be calculated. Fig. 3 shows the result of these calculations, applied to the same motor type series as before. The relation between number of poles and optimum L/D ratio is similar to that of Fig. 1, but here the optimum ratio decreases with increasing output. This is due to the fact that for the values of the exponents α, β and γ used in the calculation, the losses dependent on the length increase more rapidly with the main dimensions than the losses which are independent of the length.

On comparing Fig. 3 with Fig. 1 it will be seen that the optimum values of L/D for maximum efficiency are larger than those for a minimum leakage factor. While

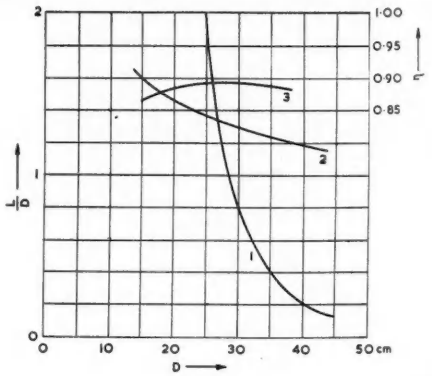


Fig. 4

this result has no general validity, usually the optimum value of L/D for maximum efficiency will be different from that for minimum leakage factor.

It is therefore again necessary to investigate to what extent we can depart from the optimum value of L/D, without appreciably reducing the efficiency. In Fig. 4, curve (1) has the same meaning as in Fig. 2, i.e., it represents the relation of L/D to D at constant load. Curve (2) shows the same relation calculated for the optimum value of L/D (eq. 7). The intersection of the two curves gives the dimensions for which, at a given load, the efficiency is at a maximum. If now the efficiency is calculated at a constant load for other values of L/D, we get curve (3). This shows that the efficiency only drops very slightly, when the ratio L/D is twice or half its optimum value. Hence, such a departure from optimum dimensions is permissible also with respect to efficiency.

From Figs. 1 and 3 it follows that, in order to achieve the optimum electrical properties, motors should be built longer than is the custom in Europe. However, other considerations such as cost of manufacture enter the picture, and it must also be borne in mind that the calculations were restricted to one particular type of motor.

Nevertheless, these results are sufficiently significant to invalidate the general criticism that various European manufacturers choose the main dimensions of their 3-phase motors unsuitably, making the length too great in proportion to the diameter.[3] No simple criterion exists for the determination of this ratio, but if the chief aim were to ensure optimum electrical properties, the motors should perhaps be built longer than is now customary !

REFERENCES

(1) ARNOLD and LA COUR: Die asynchronen Wechselstrommaschinen, 1. Teil, 1909, p. 344.

(2) CERNAVIN and GÖTZ: Berechnungen von Typenreihen im Drehstrommotorenbau, Part II, *E.T.Z.* 65 (1944), No. 51/52, p. 437.

(3) WEISS: Kurze oder lange Drehstrom-Asynchronmotoren. *E.T.Z.* 72 (1951), No. 18, p. 539.

RUSSIA

An Objective Photometer for the Measurement of Low Intensities of Illumination

By M. A. OSTROVSKIY. (From *Elektritchestvo*, No. 11, 1952, pp. 62-64, 3 illustrations.)

Outdoor measurements of the intensity of illumination require in practice a robust and portable instrument for use by semi-skilled personnel. Subjective principles of measurement are ruled out and the author describes a specially developed objective instrument. In this, the discharge frequency of a condenser which stores electrical energy controlled by a phototube is measured by counting glow lamp flashes.

EFFICIENT operation and control of lighting installations, especially those governed by statutory regulations, call for an instrument capable of measuring intensity of illumination within a range of 0·1 and 50 lux, with an accuracy satisfactory for practical purposes.

In recent years, objective photometers incorporating a selenium photocell have been widely used. However, for the measurement of illumination in outdoor lighting installations, these photometers are not particularly suitable owing to their inadequate sensitivity. For the measurement of an intensity of about 0·1 lux, the largest practical surface area of the photocell (about 20 cm²) demands that the galvanometer shall be sensitive to currents of 0·05 μA or less. The construction of a portable photometer for outdoor work embodying a galvanometer of such sensitivity has not been found practical. It should be noted that an increase in the area of the light-sensitive element does not substantially raise the sensitivity of the photometer, because the resistance of the barrier layer of the photocell is simultaneously reduced and thus the integral sensitivity of the photometer inevitably falls.

A large number of different designs of photometers exist which are based on a subjective method of measurement. The most suitable for the measurement of low values of illumination intensity has been described in Ref. 1. However, this equipment shares the drawbacks of all subjective methods of measurement, apart from its complexity in manufacture and operation.

For outdoor lighting installations there is no need for any particularly high degree of accuracy. It is hardly justifiable to face the difficulties of subjective photometric evaluation under outdoor conditions and with personnel usually unskilled in such measurements.

These considerations lead to the formulation of the following set of requirements to cover a desirable instrument for the measurement of outdoor illumination.

(1) The instruments must permit measurement of lighting intensity in the range of between 0·1 and 50 lux.

(2) The instrument must be simple in use and portable.

(3) The permissible error must not exceed ± 10 per cent.

The development of such an instrument was undertaken by the Moscow Institute for Civil Engineering in 1950-51 and a prototype photometer was produced which satisfies the above requirements.

It was found that the purpose of the desired instrument could best be served by a principle expressed in Ref. 2 as the ' storage of electrical energy.' The same principle was utilised by D. A. Shklover in the development of an instrument for the measurement of ultra-violet radiation (Ref. 3).

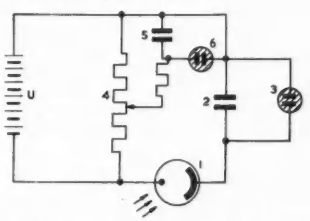


Fig. 1. Circuit diagram illustrating principle of instrument.

The circuit diagram is shown in Fig. 1. Exposure of the phototube (1) generates in the circuit a photo-electric current i, which charges the condenser (2). This process goes on until the condenser voltage U_c reaches the striking voltage U_s of the neon lamp (3). The neon lamp than lights up and the condenser discharges via the lamp until the condenser voltage falls below the extinction voltage U_e of the neon lamp and the discharge is interrupted. After this, the condenser is charged again and the process is repeated.

If the difference $U_s - U_e$ exceeds the saturation voltage of the phototube, the photo-electric current i will not alter as long as the illumination intensity E

to which the photo tube is exposed remains constant. Consequently,

$$i\triangle t = (U_s - U_e)\,C$$

where $\triangle t$ is the time interval between consecutive flashes of the neon lamp.

On the other hand,

$$i = \alpha ES,$$

where α = is the sensitivity of the phototube and S = is the area of the phototube.

Hence

$$\triangle t = \frac{(U_s - U_e)\,C}{\alpha ES}$$

Thus, the time interval between consecutive flashes of the neon lamp is inversely proportional to the intensity of illumination, and to the surface of the phototube. The number of flashes in a given time interval can, with suitable calibration of the instrument, be used as a measure of the intensity of illumination.

Since visual counting of the number of flashes is not always convenient, the circuit may include a telephone receiver in series with the neon lamp. The number of flashes is then translated into a number of clicks in the telephone. It must be remembered, however, that the presence of a large resistance in the circuit of the neon lamp affects the flashing frequency and the discharge time of the condenser. An increased resistance increases the frequency, shortens the time interval of condenser discharge and reduces the magnitude of the discharge current and, consequently, also the intensity of the signal. This is explained by the fact that, in the presence of an additional resistance, the condenser discharges down to a voltage U_e', which exceeds the extinction voltage U_e of the neon lamp by an amount equal to the voltage drop across the resistance. Therefore, the above expressions for $\triangle t$, in the presence of a resistance in series with the neon lamp, is modified into

$$\triangle t = \frac{(U_s - U_e')\,C}{\alpha ES}$$

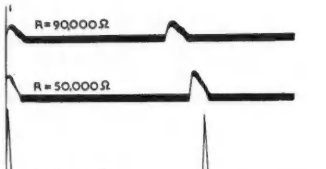


Fig. 2. **Oscillographic records of discharge current.**

In Fig. 2 oscillographic records of the discharge current at different resistances in the neon lamp circuit are illustrated. Inspection of these records shows that, by changing the resistance from 5,000 to 90,000 ohms, the frequency of the signals increases by a factor of 1·5. Consequently, by an appropriate selection of the resistance of the telephone receiver or by the incorporation of an additional resistance in the circuit, it is possible to raise the signal frequency at a given intensity of illumination and consequently to increase the accuracy of measurement.

The sensitivity of the circuit examined here is determined by a photoelectric current of about 10^{-9} A. A further increase in sensitivity demands an improvement in the quality of insulation. For vacuum antimony-cesium phototubes, a value of photoelectric current of 10^{-9} A corresponds to an intensity of illumination of about 0·05 lux. In this case, with a condenser capacity of C = 300 $\mu\mu$F, the interval between signals is 4 to 5 seconds. Widening of the range of measurement towards larger values of illumination intensity is achieved by the introduction of condensers of appropriate capacity.

Tests carried out have shown that variations of temperature and moisture within limits encountered in practical operation have no substantial influence on the sensitivity of the system. However, it must be remembered that in the flash of the neon lamp an unstable discharge is observed, caused by the emergence of a photoelectric current from the surface of its electrodes. For this reason, stabilisation of the operation of this scheme demands the screening of the neon lamp from the direct incidence of the source of illumination.

The registration of time intervals can be carried out by means of stop-watches. However, in the measurement of low values of illumination under outdoor conditions, this procedure is inconvenient. A special timing circuit is therefore incorporated, which consists of the potentiometer (4) (see Fig. 1), another condenser (5) and a second neon lamp (6). With a suitable choice of resistances and at a suitable position of the potentiometer slide, it is possible in practice to obtain any desired flashing interval of the timing lamp. Insofar as a variation in battery voltage affects the charging time of the condenser in the timing circuit, a knob controlling the potentiometer must be provided on the control panel of the instrument to retain a means of periodic adjustment of the circuit. It is also possible to introduce a telephone receiver in series with the timing neon lamp and time signals are converted into clicks audible in a telephone receiver like the flashes in the working circuit.

One receiver of a head set can be switched into the working part of the system and the other into the timing part.

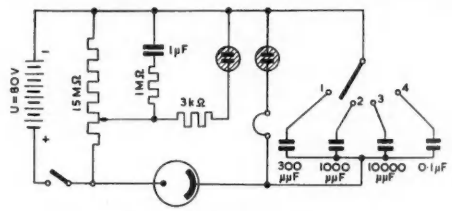


Fig. 3. **Circuit diagram of photometer.**

The above considerations served as a basis for the development of the prototype photometer with a circuit as shown in Fig. 3. The instrument contains a vacuum antimony-cesium phototube having an especially low saturation potential of 12 V. The sensitivity of the phototube is 41 μA/lumen. The neon discharge lamp has a flash-over potential of 58 V. Thus, a high-capacity battery of U = 80 V could be employed. The instrument has four measuring ranges, namely, 0·06-0·6, 0·6-6·0, 2-20, and 10-100 lux.

The interval between the flashes of the neon lamp in the timing circuit is 10 sec. The instrument has given full satisfaction in laboratory and outdoor tests.

REFERENCES

(1) Y. B. Zilverblat and M. A. Ostrovskiy: Street lighting in towns. Published by the Ministry of Town Administration of the R.S.F.S.R., 1951.

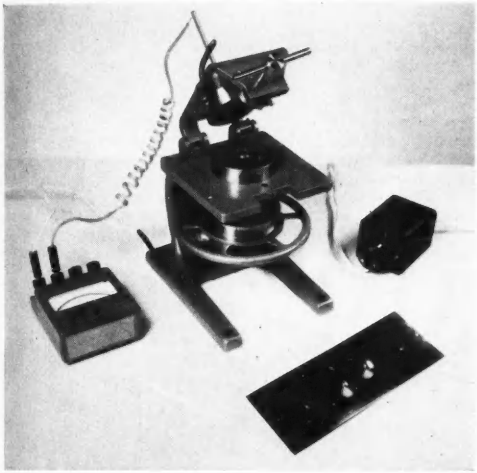
(2) V. A. Kizel and S. A. Drooker: *Zavodskaya Laboratorya*, Vol. 9. No. 5-6, 1940.

(3) D. A. Shklover: Ultraviolet radiations and hygiene. *A.M.N. U.S.S.R.*, p. 52, 1950.

New Materials, Processes and Equipment

LACQUER TENSOMETER

A new material testing instrument has been produced by AB Alpha, Sundbyberg, Sweden, one of the L. M. Ericsson group of Companies, represented in England by Messrs. J. W. Jackman & Co. Ltd., Manchester 3. The instrument, which has been developed in co-operation with the Swedish Mechanical Trade Institute and the Central Research Laboratory of the Swedish Paint and Varnish Industries, is a lacquer tensometer suitable also for testing any surface finish which gives an electrically non-conductive coating to metals.



As shown in the accompanying figure, a steel ball in the tensometer is pressed upward against a horizontally clamped plate, producing an indentation in the plate. The test coating is on the upper surface of the plate, and extends with increasing indentation up to the point of cracking. The test plate is held by a cup containing an electrolyte. The cup is electrically insulated from the electrolyte and the test plate by a rubber lining. Thus, the test coating is acting as an insulator in a circuit between electrolyte and test plate. This circuit contains the transformer, giving 2V, a milliammeter and a platinum electrode. When cracks start to develop, the insulation resistance is reduced and the current is shown on the ammeter. The ball is pressed upward by a screw fixed on the handwheel, the latter being calibrated to indicate the depth of indentation. For each depth, the current is read, and both values are plotted. The more or less sudden rise in current coincides, as microscopic inspection shows, with crack development.

The plate is firmly held by means of a locking device, and the insulated cup is filled with electrolyte by means of a pipette with rubber ball, prior to commencing the test. The same pipette is used for removing the electrolyte after concluding the test. For uniform results, the test plate must be of a defined quality carbon steel, 0·3 mm thick and 80 mm wide, and capable of withstanding an indentation depth of 8 mm without breaking. The coating to be tested should not exceed 0·03 mm, and coatings to be compared should be of the same age and obtained by the same treatment.

A suitable electrolyte is obtained by dissolving 44 grams of calcium chloride and 14 grams of ferro chloride in 100 grams water. A wetting agent soluble in water may be added, if required.

ELECTRONIC THERMOMETER

The many limitations and disadvantages inherent in other temperature measuring systems have led, in recent years, to the use of electronic methods which are both more accurate and more flexible in application than those which they replace. Control of temperature, in particular, is much more readily achieved, as ample power can be made available with no loading of the measuring system.

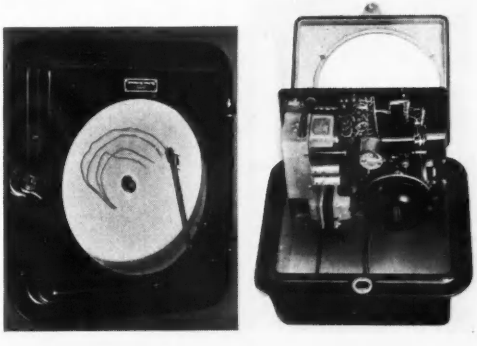
Fielden (Electronics) Ltd., Wythenshawe, Manchester, have produced a range of simple, robust instruments which are reliable, accurate and easy to operate. Nothing has been sacrificed for the sake of cheapness and the aim throughout has been to produce the best.

The Fielden Electronic resistance multipoint thermometer holds the following advantages over many other methods of temperature measurement :

Long term high accuracy and reliability ; simple design—easy, inexpensive maintenance ; no galvanometers or fragile mechanisms ; interchangeability of resistance bulbs to standard, without recalibration ; elimination of cold-end compensation ; power operated recording mechanism ; rapid pen response ; reduced thermal lag ; distant indication, no restrictions due to use of capillary tubing ; continuous balancing ; no batteries required ; and low capital cost.

A 4-point turret pen ensures that the appropriate coloured ink, carried in separate reservoirs, is selected for each trace. The pen is positioned radially by the bridge-balancing servo-motor. Turret rotation is actuated by a plunger concentric with the rotating bush which carries the pen arm. The turret is rotated through an angle of 90 deg by means of a steel pawl and the pen assembly is then accurately located by a square shoulder which engages a flat spring. An important feature is that, at any time, the rotating turret mechanism may be arrested in any one of its four positions by means of a switch on the front panel. The unit then becomes a single-point continuous recorder of the temperature at the selected point.

A Sangamo-Weston resistance bulb is used as the temperature sensitive element. Its rugged construction provides a dependability which has been proved under the most arduous conditions in the services. These



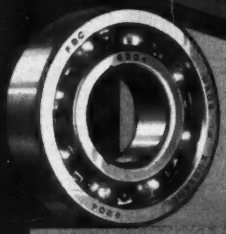
RADIAL LOAD

10,000 R.P.M.

121° C

END LOAD

1000 hours



GREASE TESTING

The ball-bearing of today gives a considerably higher performance than the ball-bearing of the past, and these increased demands make corresponding demands upon the grease employed. The Aeronautical Inspection Directorate and the petroleum companies test grease by the forthright method of testing its effect upon the durability of a ball-bearing running at high speed in an electrically heated oven :—' the grease shall lubricate the bearing satisfactorily for not less than 1000 hours running.'

COMMENT *In order to eliminate, or at least minimise, the effect of the bearing as a 'variable', it is essential that the bearing is manufactured to very high precision limits. We are proud, therefore, to say that we have the distinction of supplying these test bearings.*

FBC ALL-BRITISH

TRADE MARK

FISCHER BEARINGS COMPANY LTD., WOLVERHAMPTON *Fischer Bearings Company Ltd. and Timken-Fischer Stockists Ltd., Birmingham, are both subsidiaries of British Timken Ltd.*

bulbs cover a range of —200° C to + 500° C and can be supplied in lengths of 3 in. to 36 in.

Circular charts 11 in. in diameter are available to cover ranges within the limits of the resistance bulbs. An 8 in. dial panel mounting instrument provides single or multi-point indication.

An instrument for continuous recording can be supplied as a simple recorder or recorder controller. The latter incorporates cam-operated contacts for electrical ON/OFF control in conjunction with magnetic valves, etc.

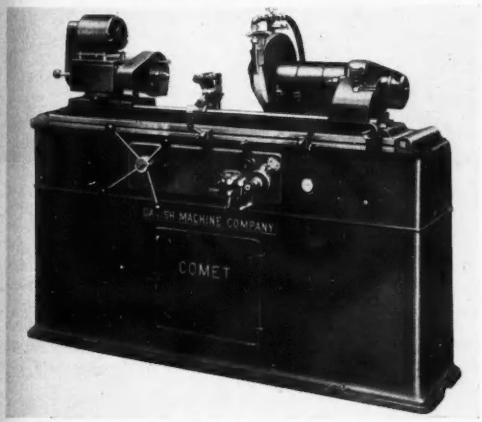
A pneumatic controller is available with simple proportional control only or with second and third term functions for more complicated processes. The ample driving power available from the servomechanism permits the use of an original pneumatic system which avoids the conventional nozzle and flapper technique.

CYLINDRICAL GRINDING MACHINE

Known as the "Comet," this universal cylindrical grinding machine admits between centres a maximum length of workpiece of 2 ft 5⅛ in. It is made by the Danish Machine Company A/S, and is available in this country through George Hatch Ltd., 3 Queenhithe, London, E.C.4.

The grinder has a wide field of application besides cylindrical grinding; it may be used for conical grinding, and as it is possible to swing the headstock through 90 deg. either side, it may be used as a surface grinder.

The bed is a one-piece casting with numerous internal ribs, and is provided with wide track prismatic guides for both table and grinding wheel support. The table comprises two parts, one resting on the bed guides, and one swivel table. The latter can be adjusted by means of a fine adjustment screw at the right-hand end of the table.



The pump unit comprises an oil pump, a water pump and their driving motors. The oil tank is mounted on a baseplate within the cast frame. The oil pump is fully submerged in the oil tank. It is directly coupled to its motor; the shaft is carried through a stuffing box in the well of the tank.

The hydraulic operation of the table is controlled by a simple and robust slide valve system, enabling reversing to take place without chatter. The slide valve is operated by means of an arm arranged in the front of the operating plate. Two adjustable trip blocks with fine-adjustment screws actuate the arm. The slide valve housing includes an adjustable by-pass valve for regulating oil pressure, which should be between 265 and 295 psi.

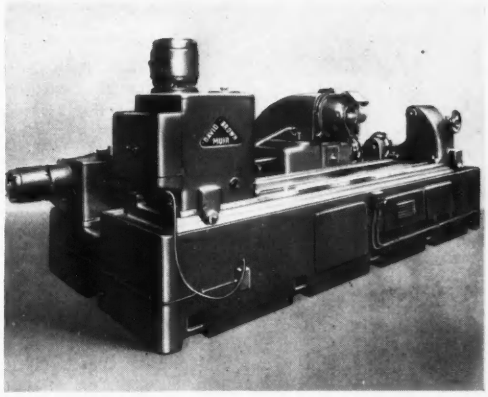
The grinding wheelhead is provided with adjustable roller bearings; power is transmitted by a Vee-belt drive.

A slight rotation of a handle in front of the tailstock displaces the tailspindle to the rear, thus allowing rapid removal and insertion of the work. A diamond holder for trueing up the grinding wheel is provided.

A fast headstock and automatic feed make this machine easy to operate. Special attachments for internal grinding are available.

HORIZONTAL GEAR SHAVING MACHINE

A horizontal gear shaving machine, believed to be the first of its type built in Britain, has recently been completed by David Brown Machine Tools Ltd., Manchester. Designed for shaving gear tooth profiles of large turbine pinions, where close tolerances and high quality finish are required, the machine, designated the David Brown-Muir S24H, will shave pinions of 4 in. to 24 in. diameter and up to 100 in. long. Embodied in the design of this machine are several features evolved by the makers through recent experience in developing a range of vertical axis shaving machines.



The S24H, which weighs 20 tons, is designed for shaving by the radial loading method, whereby both flanks of the gear tooth are cut simultaneously. If required, an oil-cooled brake can be fitted to the cutter spindle to allow single-side or selective shaving.

Guideways in the main bed provide location for the driving head and tailstock, and for the saddle carrying the shaving cutter head.

Provision is made for the fitting of work-steady brackets in any required position. Complex drives are eliminated by the adoption of independent driving units for both work driving head and cutter saddle traverse. A substantial facing locates the unit drive to the cutter head saddle.

Longitudinal hand traverse of the work head and tailstock is effected by rotating spur pinions engaging with a rack located at the front of the bed.

Designed as a self-contained unit, the work drive head is fixed to the bed and is powered by a constant speed 5-hp motor. This drive is taken through worm and helical gears, and a series of change gears gives a choice of spindle speeds ranging from 21 to 300 rpm. For setting purposes, the driving spindle can be run independently of all other machine motions.

The saddle feed gearbox, fitted as an independent unit at the rear of the machine bed, provides for longitudinal traverse of the cutter. Drive to the saddle traverse screw is supplied by a 3-hp motor and rates of feed range from 0·17 to 3·3 ipm. A rapid power traverse of 20 ipm is provided. Adjustable stops control the length of traverse and a hand-operated reversing switch is used to change the relative directions of motion.

Angular adjustment of the shaving cutter head is made by a hand-operated worm and wheel, and a vernier

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Output : 60 — 350 Amps. Current continuously variable.
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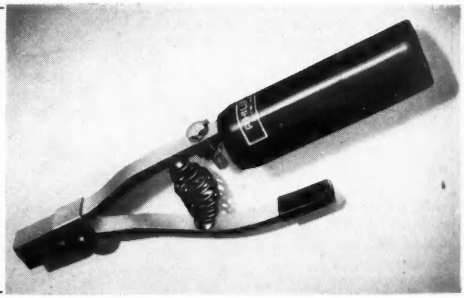

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A fully portable A.C. Welding Plant for medium fabrications, sheet-metal welding, maintenance work and garage and agricultural repairs. Low initial outlay and low running costs are special features of this unit. Input links easily adjusted to permit connections to different supply voltages — 200, 225, 400, 440 volts; single phase 50 cycles, or across 2 phases of a three-phase system.
The welding current control is continuous over the entire range of 15 to 200 amps. Two current ranges are available :—
Low range — 15 to 100 amps. O/C voltage 80/100 volts.
High range — 30 to 200 amps. O/C voltage 40/50 volts.
Approximate dimensions — 1 ft. 6½ in. x 1 ft. 5 in. x 1 ft. 11½ in.
Approximate weight — 200 lb.

For full details of complete range, write for Philips Arc Welding Catalogue PD.3515

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scale facilitates quick and accurate setting. The final fine adjustment is achieved by the use of a dial indicator which is in contact with a setting bar located by a slipping ring in the cutter head.

A hand-operated in-feed slide engages the shaving cutter in mesh with the gear, and three handwheels, incorporating graduated scales, enable adjustment to be made from any of three positions.

The electrical control gear is mounted on a panel at the rear of the machine and an isolator switch is incorporated in the panel door. The various motions of the machine are controlled by duplicated push-button stations, one of which is at the front and one at the end of the machine. A rotary change-over switch selects the direction of rotation of the driving spindle relative to the direction of feed, and limit switches prevent over-running.

Automatic lubrication systems are fitted to the work driving head and saddle feed gearbox. Saddle guide-ways and feed screws are lubricated by a hand-operated pump, and gears in the in-feed bevel box run in an oil bath. Other moving parts are provided with oil nipples.

A self-contained motorised gear pump supplies the shaving cutter with a continuous flow of cutting lubricant which subsequently passes through two magnetic filters and a box-type strainer before being allowed to re-circulate.

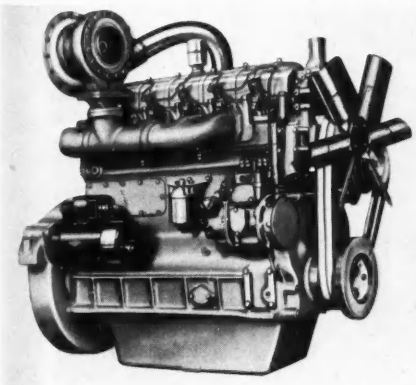
TURBOCHARGED DIESEL ENGINES

The Waukesha Motor Company, Waukesha, Wis., has extended the advantages of turbocharging to relatively small engines in exploiting the fairly recent availability of commercially produced turbochargers of small size.

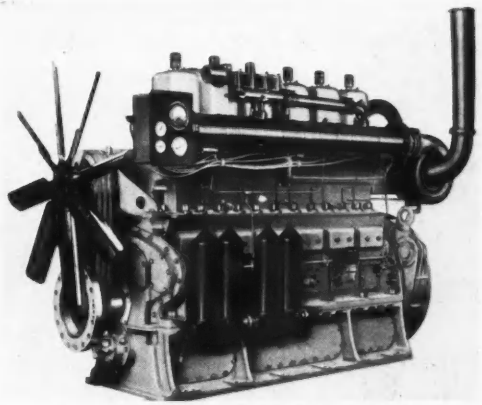
Turbochargers have been applied to five basic diesel engine sizes, ranging from 185 to 570 hp, three for transportation or industrial service and the two largest as complete power units for industrial service. Application to transport engines is particularly noteworthy.

All engines incorporate the Waukesha spherical fuel combustion chamber. Design of the spherical cavity and the tangential throat opening into the main combustion chamber promotes controlled turbulence and aids in obtaining clean, complete combustion. An insulating air space surrounds the lower half of the combustion chamber and the retained heat is given up to the air during compression. This reduces ignition lag, and since the amount of heat retained will vary with the load, this feature has the effect of advancing or retarding the time of combustion. The upper half of the chamber, including the injector mounting bore, is water-jacketed.

All models use American Bosch injection equipment and single orifice, pintle-type nozzles. The 185-hp model of 426 cu in. displacement, illustrated here, uses a single-plunger, flange-mounted injection pump, and the four larger models use the multi-plunger, bracket-mounted pump.



Turbocharged engine developing 185 hp at 2,800 rpm.



Turbocharged engine developing 570 hp at 1,200 rpm.

Variable speed centrifugal governors, mounted on the injection pumps, are used on the smaller models, while the larger ones have centrifugal type governors operated through the engine gear train.

Schwitzer-Cummins turbo charges are being used on the 185 hp model, and Elliot turbo chargers as standard equipment on the four larger models. On the three smallest engines the turbocharger is ordinarily top-mounted on the exhaust manifold. On the two large industrial units the turbocharger is mounted on the rear end of the exhaust manifolds as can be seen from the illustration. At top engine speeds, the turbocharger rotors turn at a speed of 35,000 to 40,000 rpm.

Stellite-faced valves and stellite inserts are standard; full pressure lubrication is common to all models; drop-forged, extra-heavy crankshafts with large-diameter hardened and ground journals are furnished with or without counterbalancing, depending on service requirements.

NEW DIESEL ENGINE

The Swedish company Bolinder, represented by Bolinder's Company Ltd., 4 Lloyd's Avenue, London, E.C.3, is introducing a new cold-starting four-stroke diesel with direct injection and overhead valves, in two sizes with three and four cylinders respectively. Progress is also being made with one and two cylinder engines. The engines are designed so that cylinder liners, pistons and a number of other essential parts are common to all types.

The new Bolinder is made into 33 different products for tractor, industrial, power pack, a.c. and d.c. generator sets and for Marine purposes. The three or four cylinder marine unit is supplied with either 1·5 to 1 or 3 to 1 reduction gear. Combustion is of the direct injection type with a toroidally shaped bowl in the top of the aluminium alloy piston which is fitted with three compression rings, two oil scraper rings and a fully floating gudgeon pin. The top compression ring is chromium plated.

The cylinder block and crankcase are of cast iron monobloc construction. The cylinder covers are of molybdenum cast iron with ample water space and carry multi-hole injectors. Valve seats are of special alloy and easily renewable. Removable wet cylinder liners of special centrifugal cast iron are fitted.

One inlet and one exhaust valve are fitted for each cylinder. These are made from heat-resisting steel,

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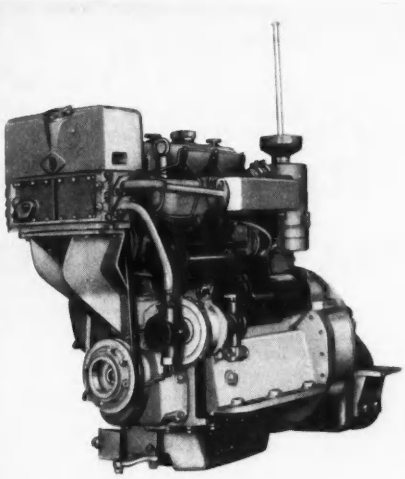


the exhaust valves being stellite-faced. The valve gear is pressure-lubricated, and a breather valve in the cylinder head cover prevents condensation and rust.

A centrifugal governor is totally enclosed and built integral with the fuel pump for variable speed adjustment between 500 and 1500 rpm.

The engine is designed for electric starting with 12-volt 4-hp starter motor and fitted with belt-driven 130 W 12-V generator with built-in automatic voltage regulator for battery charging. For easy hand starting, a decompression gear is fitted as standard equipment.

TOOL MILLING MACHINE

The Thiel 58 punch and die milling machine, designed in the early 'thirties, shown in the right-hand illustration, has proved its value in the toolroom for the manufacture of punches, dies, gauges, profiles, jigs and fixtures.

A new machine, the Thiel 158, has now been designed and produced, based on the experience gained in this German Company's own watch factory in the building of this type of machine tool. It is shown at the left of the illustration; it is slightly larger and easier to operate than the older No. 58 machine with which all attachments remain interchangeable.

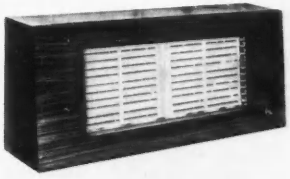
The new 158 machine represents a thoroughly up-to-date version of the old, still more versatile and more accurate. It includes the following improvements :—

Motor and switch gear are built into the machine and are yet easily accessible. All gearboxes are inside the machine column. Spindle drive and feeds are independent of each other. Feed screws are hardened and ground. Throat depth has been increased. Vertical and horizontal collets are interchangeable. The vertical spindle drive can be isolated from the horizontal spindle drive. The vertical head can be left in position whilst using the horizontal spindle.

The position of the vertical spindle in relation to the horizontal spindle is such that the spindle nose of the vertical spindle is above the centre of the horizontal spindle, thus obtaining a large distance between table and vertical spindle.

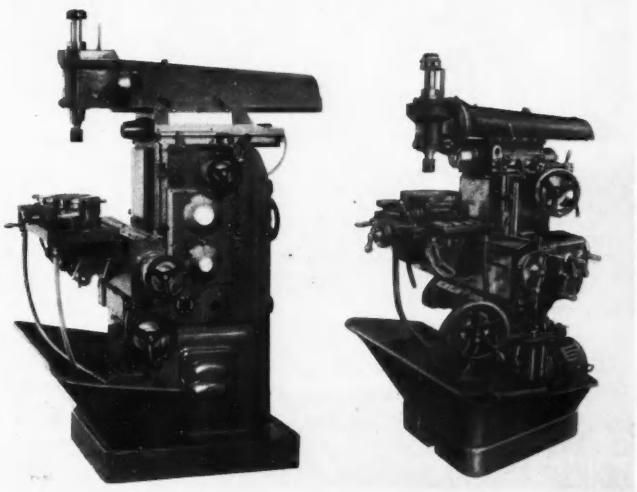
PRODUCTION OPERATION TIME RECORDER

This recorder has been designed by F. C. Robinson & Partners Ltd., Manchester, to provide managements with an automatic, instant and indelible time record of the periods of operation of a number of different machines or processes.



It consists, basically, of a white time-calibrated strip chart driven at a normal speed of 2 in. per hour by a reliable electric clock movement from right to left across a window 16½ in. wide. At the right of the window are ten electrically operated pens, each of which is connected by inexpensive wire to a separate machine. When a machine is started, its associated pen draws a clear, indelible, black line on the chart. As soon as the machine stops, the black line terminates in a clear, square and accurate end, enabling "off" periods of 30 seconds or more to be observed clearly from a number of feet away. No fluid or ink of any kind is used and the pens will not clog or require cleaning. They will last indefinitely without attention.

No batteries are required because the pen operating current of approximately 0·1A at 16V is supplied by the instrument itself. There is no danger of fire, and light twin wire can be used between the recorder and individual machines. For most purposes, simple relays connected across the motor terminals of the machines are all that is needed to actuate the pens.



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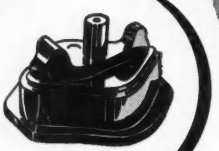

. . . . CASTINGS

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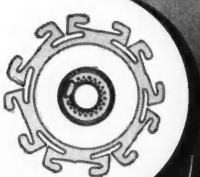

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRIC MACHINERY

Proof Tests on High-Voltage Condenser Bushings

By M. M. NEKRASOV. (From *Elektritchestvo*, *Russia*, No. 6, 1952, pp. 15-19, 5 illustrations.)

OPERATIONAL experience shows that the effectiveness of proof tests differs greatly for different types of insulators. For those made of bakelite and filled with cable compound, proof tests hitherto carried out have not been very successful. The existing method consists in (*a*) measuring tanδ and (*b*) making flash-over tests at an increased voltage, both at industrial frequency. Insulators for 110 kV are also tested by measuring the distribution of voltage along the porcelain sleeve.

The author claims that the measurement of tanδ does not show up defects of the filling compound. Many such defects cannot be revealed by testing with an excess voltage. Such tests give definite results only in the case where moisture has penetrated into the internal space of the insulator or into cracks which may have formed in the filling compound. The measurement of voltage distribution along the porcelain sleeve shows up mainly the defects of the bakelite condenser. As a result of these inadequacies of existing testing methods, random failures persist even after the introduction of 100 per cent proof testing of these insulators.

The author concludes from his investigations that better reliability in operation can only be achieved by a fundamental change in the methods of proof testing. The following recommendations are given, which experience shows to eliminate substantially the remaining failures.

The measurement of tanδ should be carried out at a much higher frequency, namely, about 1000 cps, and at a voltage of about 250 V. Such tests can be carried out with a simple portable electronic oscillator of 2 W output. At this frequency the tests reveal defects in the filling compound.

The flash-over tests can be carried out at industrial frequency, but special test electrodes in the shape of hoops fixed at the top of the porcelain sleeve underneath the first two flanges must be used.

LOCOMOTIVES

Gas-Turbine Locomotive with Free-Piston Generator

(From *La Technique Moderne*, *France*, Vol. 45, No. 1, January, 1953, pp. 11-13, 4 illustrations.)

THE French Railways recently put into service a new gas turbine locomotive, constructed by the Renault Works, which differs from those operating in other countries by having a free-piston generator, instead of a turbine-driven rotary compressor, for the supply of the air required for combustion.

Previous types of gas-turbine locomotives included the following features which have hampered somewhat their development: (1) an important amount of power is required for air compression; (2) the weight and cost of a rotary compressor are rather high; (3) in spite of the use of temperature-resisting steels, temperatures of 700-750° C cannot yet be exceeded at the outlet of the combustion chamber without affecting the operation of the turbine blading and this limits the overall efficiency; moreover, it is not possible to consider cooling the turbine blades.

Free-piston generators, on the other hand, can reach without difficulty a temperature of 1800° C in the combustion chamber, since the hot gases are adiabatically expanded, owing to the work absorbed by air compression, before being used in the turbine. These gases are mixed with the scavenge air and enter the turbine at a temperature not above 500° C. Furthermore, the cooling of the cylinders, pistons and other components in contact with the gases is not particularly difficult. Owing to the high temperature of the combustion gases, the overall efficiency should be higher than that of the straight gas turbine, since it is a function of the temperature drop of the gases between the combustion chamber and the turbine exhaust. All the power available on the shaft is used for traction. The power and efficiency (about 33 per cent) of the installation are only slightly affected by external temperature and atmospheric pressure, whereas the conventional gas turbine is very sensitive to these factors. Finally, the size and weight of the free-piston generator are comparatively small, so that this unit can easily be installed in a locomotive.

The mean piston speed of the compressor is 8·3 m/sec and the stroke is 450 mm at full load. The gas generator operating at 600 cps delivers 3·5 kg of gas per sec and this corresponds to a power output of 1200 hp.

Starting is obtained by means of a compressed-air starter, supplied by a container of 50 litres capacity. The pressure in the energy-accumulator chambers is regulated by a stabilising device. The pistons are connected together by an external system of rods and linkages which transmit no driving effort but ensure only that the pistons are always in symmetrical positions.

Unlike the pure gas turbines previously developed for railway traction, this turbine operates with a mechanical transmission. It was designed so as to be able to operate over a wide range of loads and speeds. For this purpose, it was provided with six expansion stages, instead of three as in the case of turbines with electrical generating sets, operating with free-piston machinery in power stations. The starting torque is 3·7 times the maximum-speed torque and 2·5 times the torque for maximum power. The turbine can run at 12,320 rpm. Its most economic speed, which is approximately the speed for maximum power, is at 9,000 rpm.

Operating conditions of the locomotive are controlled by regulating the pressure of the compressed air of servomotors acting on the gas generator and the turbine intake. Various safety devices are incorporated to avoid overspeeding of the turbine. In view of the low weight of the power unit, it was possible to construct a locomotive with two bogies, with a total weight of 59 metric tons.

MACHINING METHODS

Electric Spark Machining used in Profile Forming of Carbide Cutting Edges

By F. F. TCHEREPANOV. (From *Stanki i Instrument*, *Russia*, No. 4, 1952, pp. 31-32, 2 illustrations.)

AN old lathe has been adapted to carry out the operation. The machined component is the anode of a spark gap in the electric circuit and the cutting tool is the cathode. The anode is advanced slowly towards the cathode.

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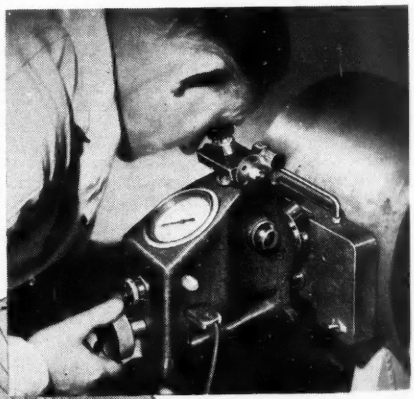

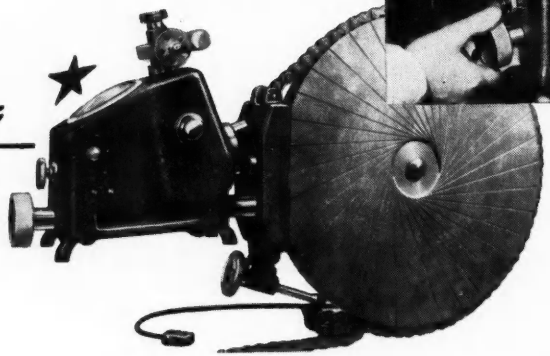

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The cathode, in the form of a metal disc, is rotated on a mandrel driven by the lathe. The peripheral speed of the electrode disc is 23 fps. The advance of the component towards the electrode is under the control of an automatic feed mechanism which ensures a constant gap between the two electrodes. This mechanism contains an electric motor connected with the sparking circuit and made responsive to the length of the gap between the electrodes. This motor drives a vertical support which serves as the clamping plate for the component. Manual feed has not proved practical.

The electric circuit is completed through a set of copper graphite brushes at the rear of the cathode disc and is of the low-voltage type. No additional capacitor was found necessary. The sparking gap is submerged in oil by means of an oil circulation system incorporating a pump with a delivery of 2 gpm. The tool support of the lathe carries a profiled cutting tool to restore periodically the profile of the electrode disc (trueing operation).

The following conditions were found to give good results in the grinding of a profile tool made of a titanium bearing carbide composition. The complete process is broken down into three parts. The first, which is the rough machining stage, is carried out at a voltage of 50 V and a current of about 28 A. Rough machining takes altogether 45 minutes and cuts the profile of the tool, but leaves an unsatisfactory surface. This is followed by finish machining carried out at 30 V and about 12 A. The second phase takes 7 minutes. The third period, denoted as the lapping operation, is carried out at a voltage of 20 V and a very low current of about 5 A. It takes 5 minutes and gives a cutting edge which is satisfactory for the rough machining of steel components. The attainment of surfaces smooth enough to give a cutting tool for finish machining is now under development. It is claimed that the total time of 57 minutes for machining the profile cutting tool compares with 1,030 minutes to give the same result by means of grinding.

PLASTICS AND PLASTIC PRODUCTS

The Theory of Screw Extruders

By R. A. STRUB. (From *Ohio State University Studies*, Engineering Series, Bulletin No. 149, No. 3, September, 1952, pp. 481-494, 8 illustrations.)

A THEORY for the calculation of output, pressure, and power characteristics of screw extruders processing plastics is worked out for any given distribution of viscosity and specific weight of the plastic along the screw. The influence of a variable viscosity across the thread depth of the screw is illustrated by two examples. A correction of the extrusion pressure due to leakage past flights is proposed. Laws of similitude are given for extrusion with and without heat exchange to the surroundings. A comparison between rectangular and semi-elliptical thread profiles is made, showing that the latter are more efficient.

WELDING

High-Current Tungsten Arc in Argon, Helium and their Mixtures

By M. SKOLNIK and T. B. JONES. (From *The Welding Journal, U.S.A.*, Vol. 32, No. 1, January, 1953, pp. 55s-64s, 11 illustrations.)

AN experimental study was made of the properties of the high-current d.c. electric arc in argon, helium and their mixtures at atmospheric pressure. Tungsten-rod electrodes were used over a current range from 10 to 100 A. Measurements of the voltage-current and the voltage-electrode separation characteristics were made along with the plasma voltage gradients in both the pure gases and in the mixtures.

It was found that this type of arc was very stable when the system was free from oxide impurities and that the cathodic processes played a major role in the arc mechanism. The results obtained suggest that the value of the anode voltage drop for the inert gas arc over the current range studied is negligibly small. At the higher currents or with smaller diameter cathodes, tungsten was able to evaporate from the cathode in sufficient quantities to influence the character of the discharge. It was observed that the properties of the arc in mixtures of gases were in between the properties observed in the pure gases. The lower ionisation potential gas, argon, had more effect on the properties of the arc in mixtures than did helium. As long as there was at least 15 per cent argon present in the mixture, the arc properties and appearance were more like those observed in argon than in helium.

Cast-Iron Crankshafts—Present and Future

(*Concluded from page* 77)

limited to small-size crankshafts with journals not much greater than 3 in. in diameter. Mention may be made of the Ford semi-steel crankshafts successfully used in various countries, the G.M. Meehanites, the Krupp and Esslingen materials, etc., but these have again mainly been employed in automobile engines and small diesels.

It is of interest, therefore, to consider what are the possible reasons for this somewhat restricted use of cast irons for larger crankshafts. It is certainly not a lack of enthusiasm on the part of the engine makers, who are always willing to carry out full-scale tests, and this applies not only to this country but equally to others where the financial resources are available. These reasons are of a twofold nature. First, the production problems of castings increase in complexity with size; special precautions are needed for pouring and cooling; materials inspection is also more difficult; and rejects represent a greater risk, so that the casting technique becomes all-important. Secondly, from the point of view of the user, i.e., the engine maker, it is essential that the cast crankshafts be guaranteed not only to have a homogeneous texture throughout, but also to conform to required values for the modulus of rigidity within fairly close limits. It is essential for the user to be sure that any batch of cast crankshafts received will have identical physical properties, such as torsional stiffness etc., in order to be able to predict stresses with reasonable certainty at the calculation stage. Moreover, though the dynamic stresses may be lower, the reduced stiffness of the cast-iron crankshafts, as compared with steel crankshafts, increases the amount of vibration amplitude and leads to the use of expensive cushioning arrangements for the gearwheels of auxiliaries.

Nevertheless, it is possible that the solution may be obtained in the form of a compromise. By producing the crankshaft in separate sections, which are subsequently joined together by means of shrink fits, the casting problem is appreciably simplified. The use of individual U-shaped portions, consisting of a crankpin and the two adjacent webs, which are fitted to the journal sections by shrinking or welding, is a well-known procedure for steel crankshafts. This solution has been tried by Sulzer and the Georg Fischer Co., using Siemens-Martin cast-steel crankthrows shrunk onto the journals, and the results are said to be most satisfactory.

For the production of cast crankshafts of medium and large size, it is essential that the processes used by various foundries be carefully compared and that all possibilities be examined of applying methods which have proved successful with smaller crankshafts. This work should be carried out by the metallurgists, co-operating at every stage with the users, that is, the engine makers. Success in this field is well worth the efforts put into it and the foresight of the firms concerned in such a project, whatever their country may be, should pay handsome dividends.

SG.19

EXPERIENCE HERE

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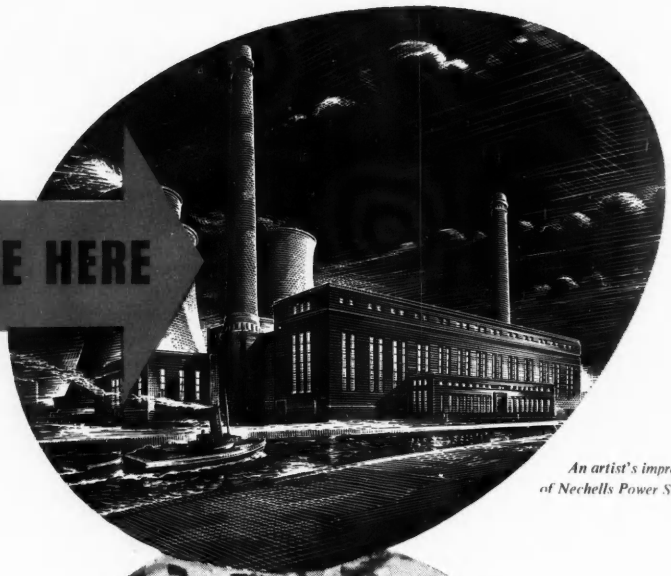

An artist's impression of Nechells Power Station

Horlicks Limited — one ICL boiler evaporating 50,000 lbs. steam/hour, fired by 'L' stoker.

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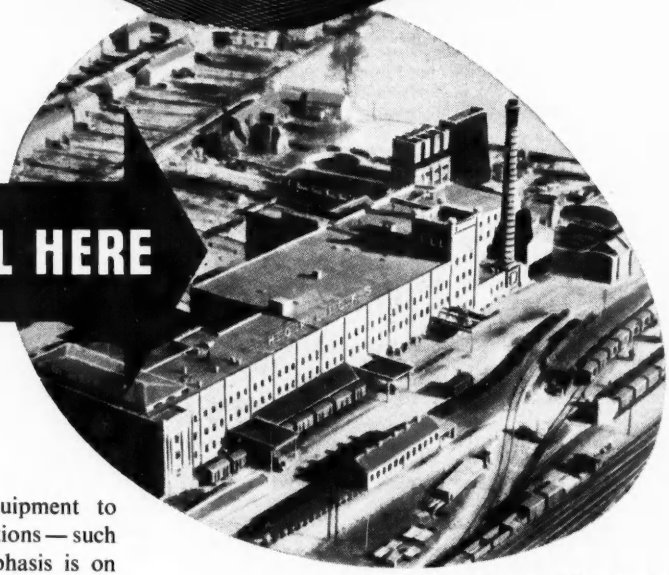

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NEWS OF THE MONTH

PERSONAL

Mr. John Aspinall, M.B.E., M.I.Mech.E., works director of Hick, Hargreaves & Co. Ltd., Soho Ironworks, Bolton, has been appointed assistant managing director of the Company.

Mr. D. T. Barritt, Mr. H. Clarke and **Mr. J. P. V. Woollam,** directors of Simon-Carves Ltd., Cheadle Heath, Stockport, have been appointed joint managing directors of the Company.

Dr. C. F. Bareford has relinquished his post as Head of the Mullard Research Laboratory, Redhill, Surrey, to become Chief Superintendent of the Long Range Weapons Establishment in South Australia.

Mr. G. A. Burridge, Secretary and Director of Burton, Griffiths and Company Limited, has also been appointed to the Board of Directors of B.S.A. Tools Limited. The appointment is also announced of **Mr. F. A. Janes** to the Board of Directors of Burton, Griffiths and Company Limited. Mr. Janes was Sales Manager for the B.S.A. Tools Group. **Mr. J. L. Parker** has been appointed Works Manager of B.S.A. Tools Limited in succession to **Mr. F. H. Harris** who has left the Company.

Mr. C. H. Flurscheim, B.A., M.I.E.E., chief engineer, switchgear department, Metropolitan-Vickers Electrical Co. Ltd., Manchester, 17, has been appointed assistant chief electrical engineer, in addition to his present duties.

Mr. P. B. Higgins, A.C.A., A.M.I.Prod.E., has been elected a director of Specialloid Ltd. and Aero Piston Ring Co. Ltd. **Mr. R. H. Hainsworth,** director and general manager, has been appointed managing director and **Mr. T. O. Hunt,** chief designer and technical manager, technical director of Specialloid Ltd.

Mr. R. Jenks, A.M.I.P.E. and member of the American Society of Tool Engineers, who has been on a visit to England has now returned to India to take up the position of Factory representative for Newall Group Sales Ltd., Peterborough.

Mr. H. H. Mardon, B.Sc.(Eng.), M.I.C.E., M.I.Mech.E., M.I.Struct.E., M.Am.S.C.E., head of the Plant Engineering Division of the British Iron and Steel Research Association, is relinquishing his position to take up the appointment of Chief Project Engineer, Messrs. Ashmore, Benson, Pease and Company. **Dr. H. R. Mills, Ph.D., B.Sc.(Eng.), M.I.Mech.E.,** has been appointed acting head of the Division. He will remain head of the Division's Mechanical Engineering Section.

Mr. W. E. Pattman has been appointed Purchasing Manager, of Bakelite Ltd. 12, Grosvenor Gdns., S.W.1. **Mr. J. M. Lassen** is to be Sales Manager P.V.C. materials.

Clarkson (Engineers) Ltd., Nuneaton, announce that **Mr. E. S. Pearson,** Secretary, has been appointed to the Board of Directors following the resignation of **Mr. G. F. Cole** who is taking up another appointment. **Mr. C. E. Middlemiss,** Sales Manager, will, in future, be in complete charge of all home sales.

The Council of the Institute of Welding has awarded the Sir William J. Larke Medal for 1952 to **Mr. J. Rannie, M.Sc., M.I.N.A.,** for his paper " Shipyard changes with special reference to Steelwork Construction in Oil Tankers." Mr. Rannie is Welding Engineer to John Brown & Co. Ltd., of Clydebank.

Mr. Norman Tattersall, M.I.Mech.E., has been appointed chief engineer, and **Dr. Ing. A. Mueller,** chief development and research engineer, of Leyland Motors Ltd., Leyland, Lancashire.

Mr. W. V. Wright has been appointed General Manager of the Land Boiler Division of John Brown & Company Limited.

BUSINESS NOTES

Mr. Ronald W. T. Bray, Managing Director of **W. E. Bray and Company, Limited,** manufacturers of the well-known range of dozer and loading equipment will be leaving on the 23rd April on a tour which will embrace a large area of the United States and Canada. Mr. Bray will be visiting a number of American and Canadian Manufacturers to study the latest trends in the design and use of various types of plant, together with manufacturing methods and procedures. It is anticipated that he will be returning from Canada during the latter part of June.

To celebrate their 21st birthday, **Asbury, Brodie & Co. Ltd.,** distributors of electrical resistance materials, stainless steel, cadmium, nickel anodes, oxides and salts, etc., held a most successful dinner and dance at the New Inns, Handsworth, Birmingham, on Friday, February 6th. Among the principal guests were Mr. R. M. Parry, managing director of British Driver Harris Co. Ltd., Mr. I. A. Bailey, managing director of Henry Wiggin Ltd., and Mr. George Tinker, managing director of Birlec Ltd.

" The Country loses between £300,000,000 and £200,000,000 a year through loss of production caused by bad timekeeping and unauthorised absence." That was the startling statement of Mr. Oswald Moor, Chairman of **Blick Time Recorders, Ltd.,** at the opening ceremony of the company's new showrooms and offices at 96-100 Aldersgate Street, London, E.C.1. on Friday, February 27th.

Mr. Moor disclosed that the Company now did five times as much business as before the war and that was the reason for the move from Grays Inn Road to the modern offices and showrooms in Aldersgate Street. It might not be long before even this accommodation failed to house the expanding business of Blick.

A further expansion of **Wolf Electric Tools Ltd.,** is the opening of a new office and service depot at Leeds to replace the previous service depot at 2, Park Square, Leeds, which has become inadequate to handle the ever increasing business. The new modern premises are situated in the main York, Selby, Hull road at 405, York Road, Leeds, 9, and are under the direction of Mr. D. S. Powell who is already well known to Wolf users in the area.

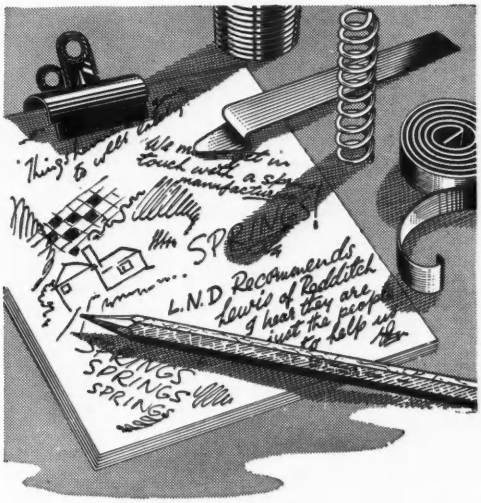
Wolf have now five factories at Slough, a service depot at Acton and five Branch offices in Birmingham, Manchester, Leeds, Bristol and Glasgow, and news of further expansion will shortly be announced.

The Fluor Corporation Limited has entered into an agreement with the **Wulff Process Co.** under which Fluor is authorised to design and construct plant for application of the Wulff Process. The process uses natural gas, ethane, propane, butane or any L.P.G. mixture as feed stock and produces low cost acetylene. It may be applied to plants making as little as one ton per day acetylene, or as much as one hundred tons per day. The process can be operated to produce substantial yields of commercial grade ethylene simultaneously. The Fluor Corporation is represented in the sterling area by **Head Wrightson Processes Limited,** Teesdale House, 24/26, Baltic Street, London, E.C.1.

WORK STUDY TRAINING IN THE WEST OF ENGLAND

A Department of Work Study has recently been established in Bristol by the Engineering & Allied Employers' West of England Association at the request of its member firms, in order to assist in their efforts to achieve greater efficiency and higher productivity.

Employers in the West of England have recognised that, if incentive schemes and payment by results are to be really effective, greater attention must be given to accuracy and consistency in the fixing of piecework rates. Furthermore, even a correctly assessed standard time is of little value unless the method by which the operation is performed has been studied and standardised.



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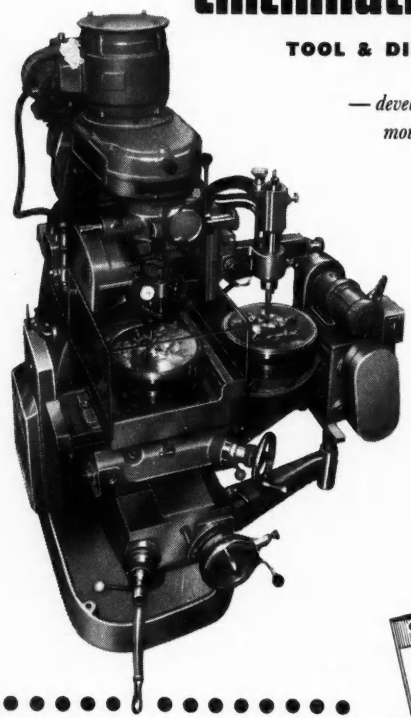

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The first task of the new Department is therefore to organise training courses in Work Study for those responsible for the planning of manufacturing methods and the fixing of piecework rates, to give them an opportunity to ensure that they are fully informed of the latest techniques of Motion Study, Time Study, Job Evaluation and Incentives. Thorough training and practice in Time Study will be given to those who need it, and, as many firms in the area are engaged in jobbing and small batch production, attention will be directed to methods of compiling standard data from which operation times can be pre-determined.

The headquarters of the department are at Brunel House, St. Georges Road, Bristol, where the programme of training opened on 3rd and 4th March with a two-day Work Study Conference for higher management. The first full training course commenced on March 9th, and lasts for eight weeks. The first four weeks are spent in full time instruction and practice at Brunel House, after which each student returns to his own factory for two weeks to put into practice what he has learnt. During this period he is visited by members of the teaching staff, who give help and guidance. The final two weeks are spent at Brunel House to consolidate the training.

Short courses for foremen will be held as the need arises, and it is probable that training which concentrates more especially on Motion Study and Method Improvement will be called for when the immediate demand for better standards of work measurement has been satisfied.

The Head of the Department is Mr. G. P. Wade, B.Sc., M.I.Prod.E., A.M.I.E.E., A.M.I.I.A., who was trained at Messrs. Metropolitan Vickers Electrical Co. Ltd., and has for the last four years been responsible for Work Study training in the Industrial Administration Department of the College of Technology, Birmingham.

He is assisted by Mr. G. R. Burn, I.Mech.E., Grad.I.Prod.E., who received his training at Messrs. Hoover Ltd., and until recently was chief Work Study Engineer at their High Wycombe factory.

In addition to teaching and following up students after the completion of their courses, the staff are also available for consultation on problems connected with manufacturing methods and labour utilisation.

LIÈGE INTERNATIONAL FAIR

The Fifth Liège International Fair, scheduled to open on April 25th, 1953, will give Belgian colliery managers an opportunity of choosing the type of equipment best fitted to bring their respective plants up to the standard required for participation in the European common market for coal and steel that opened on February 10th, 1953.

Financial aid is being made available to many of these managers, so as to allow them to purchase machinery and installations within the framework of the Five Years Re-equipment Plan drawn up by the Belgian Federation of Mining Associations.

The High Authority of the Schuman Plan treaty has just given assurances to the Government of the United States that enabled the latter to authorise the Mutual Security Agency to free Marshall aid credits, on February 16th, to the extent of one thousand two hundred million Belgian francs. Allocation to collieries is to be made through the National Society of Credit in Industry.

NEW DAVID BROWN FILM

A new David Brown colour film, "This Is Our Field," has recently been completed and will shortly be available for general showing. The film, which runs for approximately half-an-hour, has two main objectives. Firstly, it illustrates the tremendous scope of David Brown production—Aston Martin and Lagonda cars, steel and bronze castings, gears and gear units, machine tools and precision equipment. Secondly, as the main theme, it indicates how this multilateral skill and accumulated experience in many branches of engineering is reflected in another main field of David Brown activity—the production of agricultural tractors and implements. Finally, the advantages of David Brown tractor design—weight distribution, constant depth control, fuel economy—are demonstrated by scenes of various tractors and implements in action, and by charts and animated colour diagrams.

THE PROTECTION OF WAREHOUSES AND OFFICES

During recent years there has been an alarming increase in both the tempo and the volume of warehouse and office breaking, and most of them are now so carefully planned that the intruders are well away from the area before the police can be informed.

The "invisible ray" type of intruder alarm has for 25 years been an efficient method of giving warning should intruders enter a protected area. The system is both simple and reliable, and consists of projecting a beam or beams of invisible infra-red light across suitable positions. Should the beam be interrupted by an intruder, equipment actuated by a photo-electric cell is brought into operation to sound an alarm, and, if required, to switch on flood lighting.

An important new development of this equipment, to speed the capture of the intruder, is announced by Radiovisor Parent Ltd. of 1 Stanhope Street, London, N.W.1. The warning device of this Company's "Invisible Ray" Burglar Alarm can now be arranged instantly and automatically to contact the police upon interruption of the beam. In some cases it operates a direct telephone line to the local police station and sounds an alarm. A variant of this method is the incorporation of an automatic record replaying unit which announces at police headquarters the address of the building at which the attempted burglary has taken place, without giving warning to the intruders that their presence has been detected.

For obvious security reasons the location of existing installations cannot be given, but the system is already guarding buildings of considerable importance, and is also extensively employed in factories, warehouses, and offices throughout the country.

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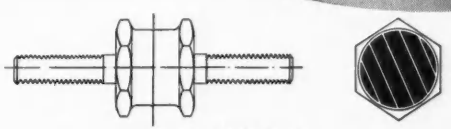

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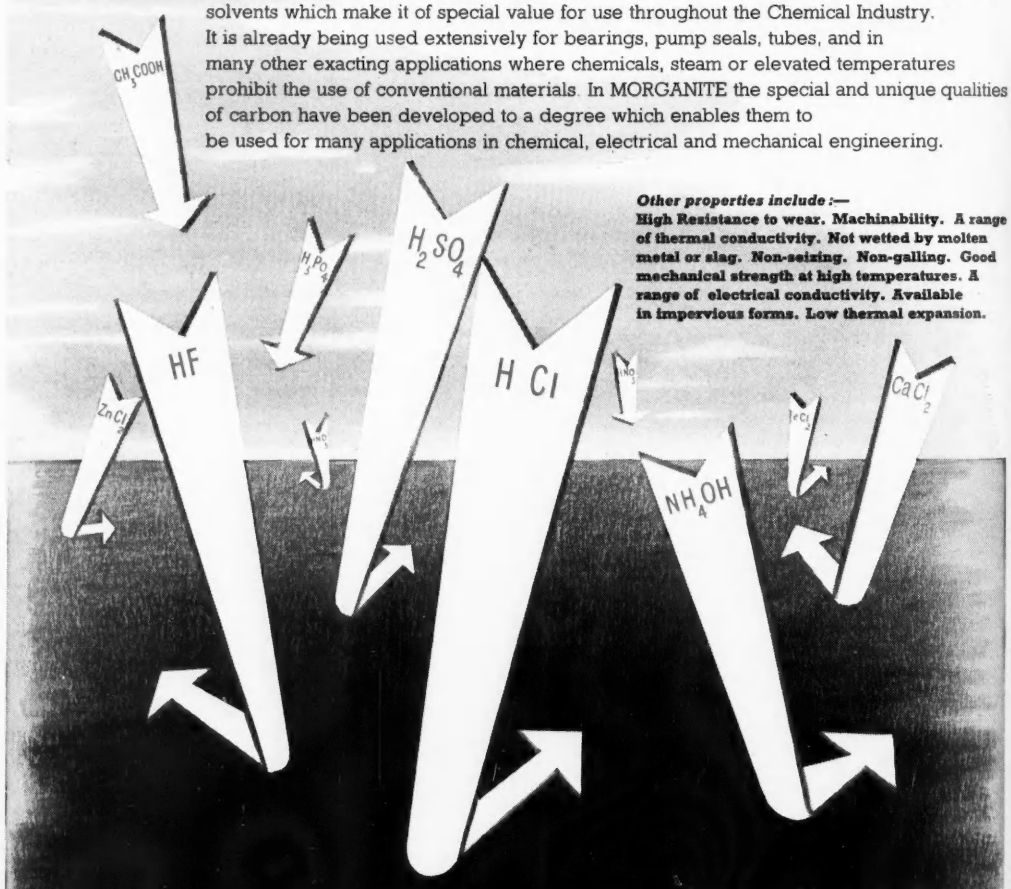

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